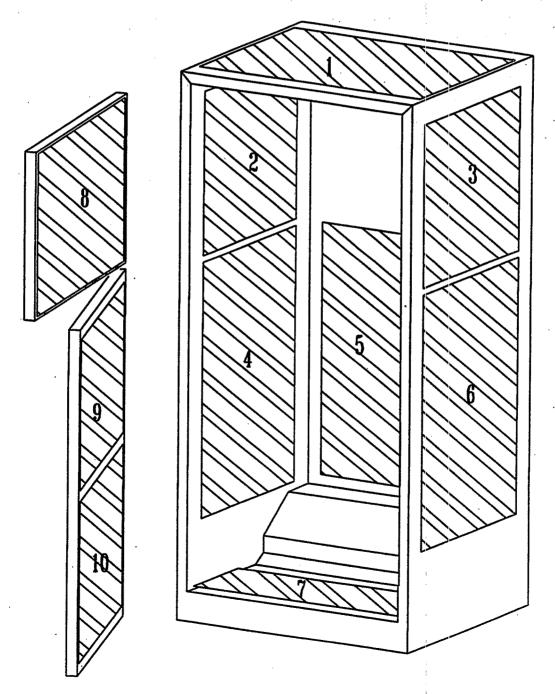
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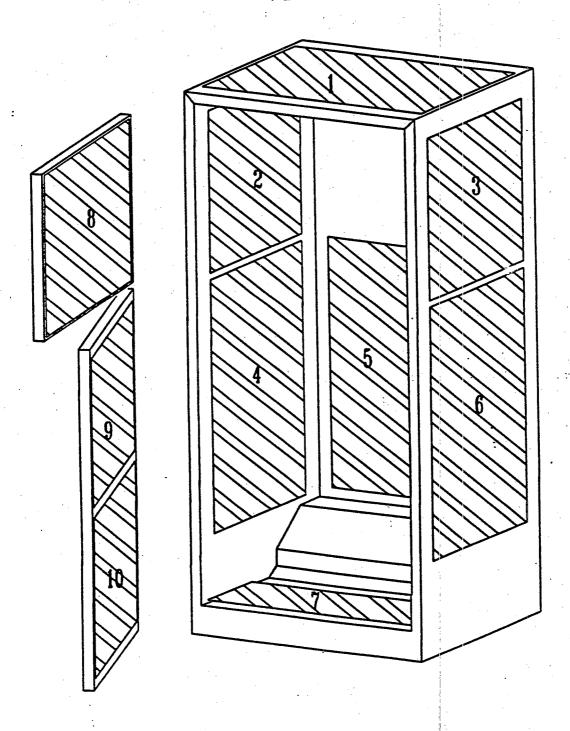
Vacuum Panel and Thick Wall Foam Insulation for Refrigerators: **Cost Estimates for** Manufacturing and Installation

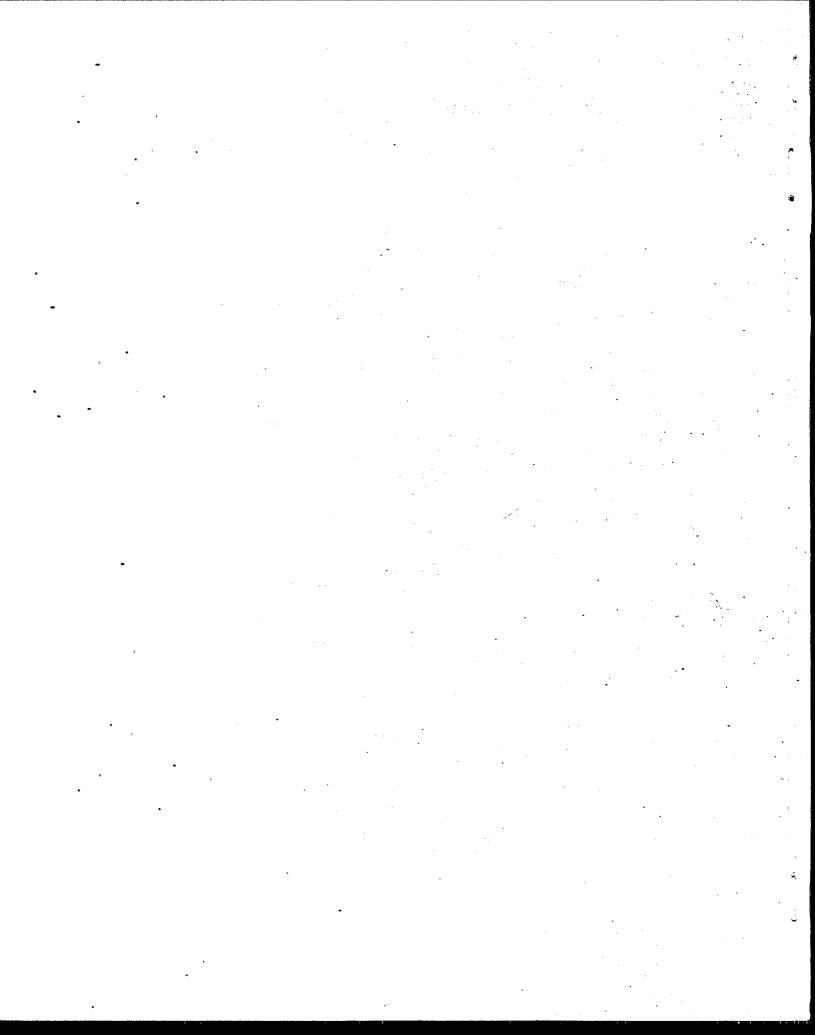


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Vacuum Panel and Thick Wall Foam Insulation for Refrigerators: Cost Estimates for Manufacturing and Installation





VACUUM PANEL AND THICK WALL FOAM INSULATION FOR REFRIGERATORS:

Cost Estimates for Manufacturing and Installation

prepared for

US Environmental Protection Agency
Global Change Division
Office of Atmospheric and Indoor Air Programs
Office of Air and Radiation

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by

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October 1992

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VACUUM PANEL AND THICK WALL FOAM INSULATION FOR REFRIGERATORS: Cost Estimates for Manufacturing and Installation

ABSTRACT

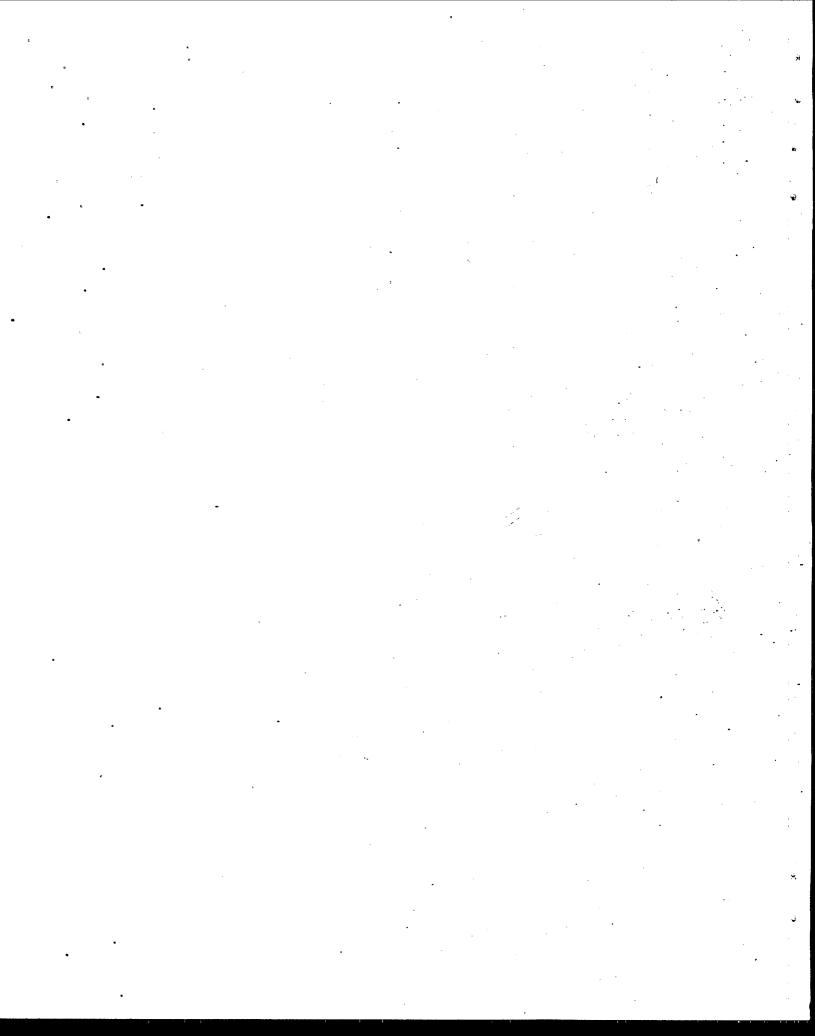
Improved insulation between the outer case and the inner liner is among the technologies available to refrigerator manufacturers to achieve significant reductions in energy consumption and the pollution associated with its generation. One approach is to add more insulation to the refrigerator cabinet. A second, "super insulation", is a developing technology which would allow refrigerator manufacturers to significantly improve energy efficiency without compromising the internal to external volume ratio of the refrigerator. One approach to super insulation is the use of vacuum insulation panels (VIPs).

The fixed and variable costs for these two cabinet insulation technologies are evaluated in this study. The manufacturing costs for VIPs are examined by developing the material, process and equipment requirements for producing and transporting VIPs on a mass production basis. VIP installation costs are established by developing a generic refrigerator assembly line and then the material, epuipment and process modifications required for receiving, storing, delivering, and installing VIPs into refrigerators. Plant and component modifications are also developed for the added foam approach.

Raw material bulk densities suggest that the VIP plant be located adjacent to the silica plant to minimize transportation cost. Silica processing must be optimized between the silica plant and the VIP plant to minimize the required investment in plant and equipment.

Trade-offs between VIP plant efficiency and refrigerator energy efficiency must be made during development to determine the best mix of panel dimensions.

Existing refrigerator assembly plants can be retrofit to receive and install VIPs, but some



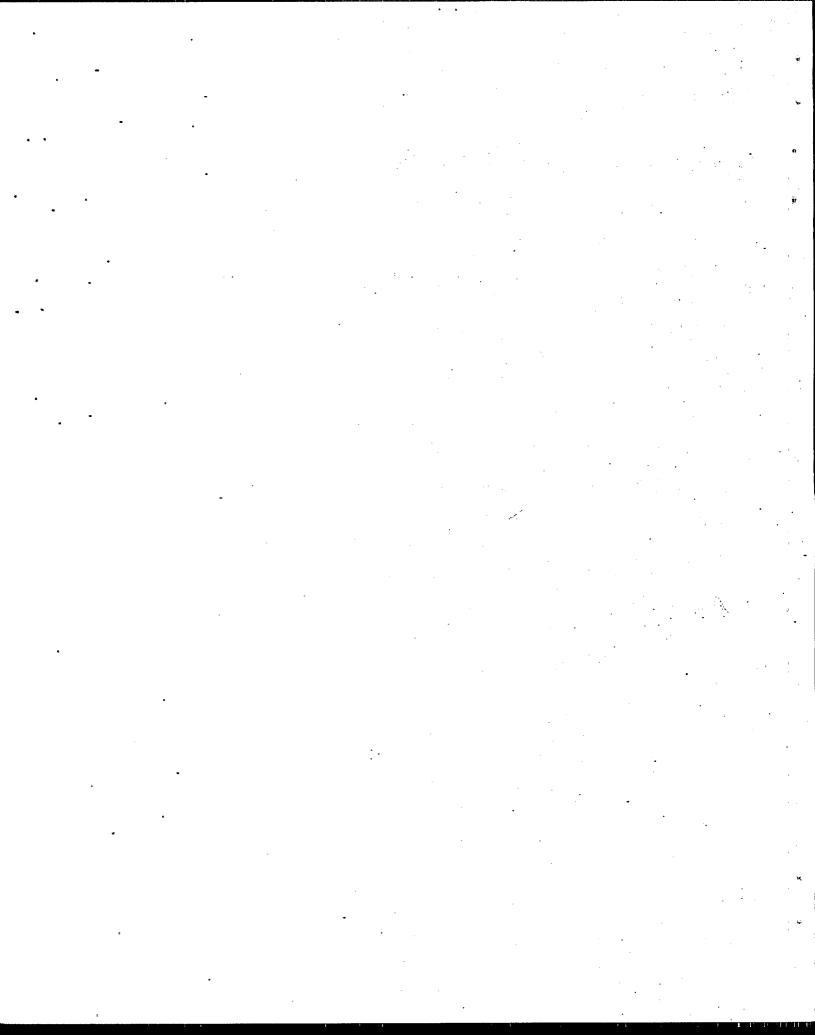
may require significant rearrangement. The technology to install VIPs into refrigerator cases and doors exists now in some plants.

Thickening the foam insulation may be more cost effective on smaller refrigerators (<20') where kitchen dimensions are less limiting and where internal/external volume ratios are less important.

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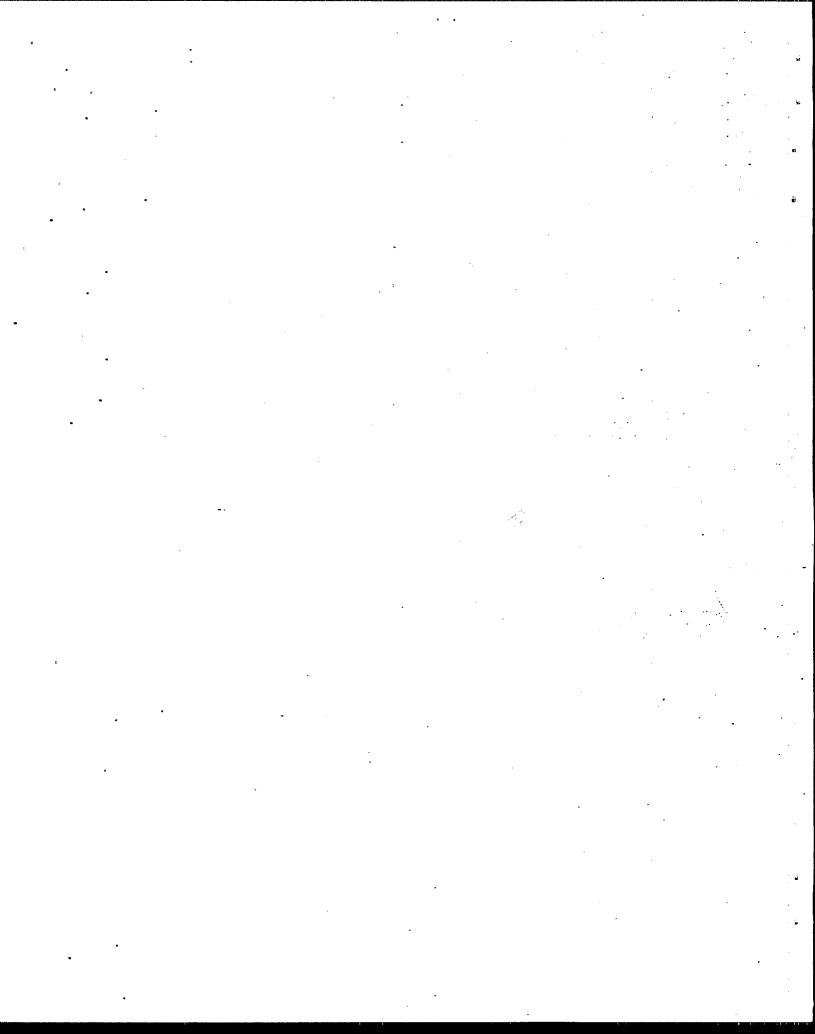
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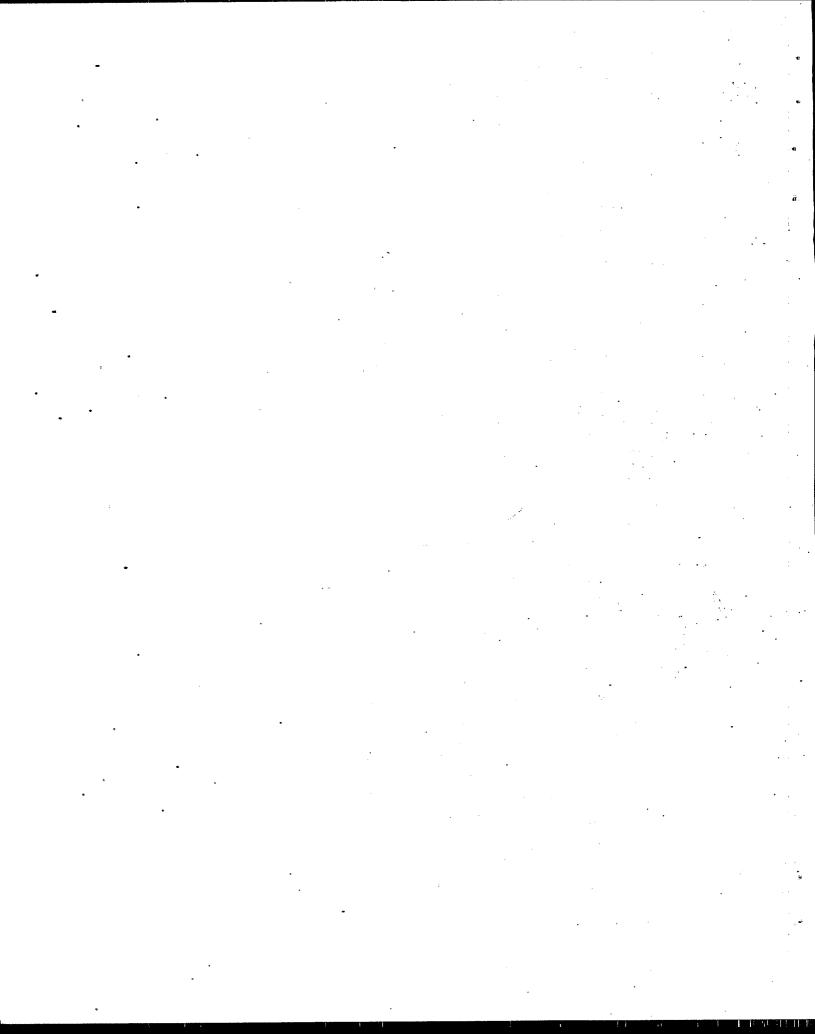
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ABBREVIATIONS

AGV—Automatic Guided Vehicle

Board Foot—A volume element 1' x 1' x 1"

CFC—Chlorofluorocarbons

DOE—Department of Energy

K—A specific property of a conducting material defined as the quantity of heat conducted across a unit area normal to the flow path in unit time and for unit temperature gradient along the flow. Expressed as Btu-IN/HR-SQFT-DEG F

NAECA—National Appliance Energy Conservation Act

ORNL—Oak Ridge National Laboratory

Torr—pressure equal to a column of mercury one millimeter high.

VIP—Vacuum insulation panel

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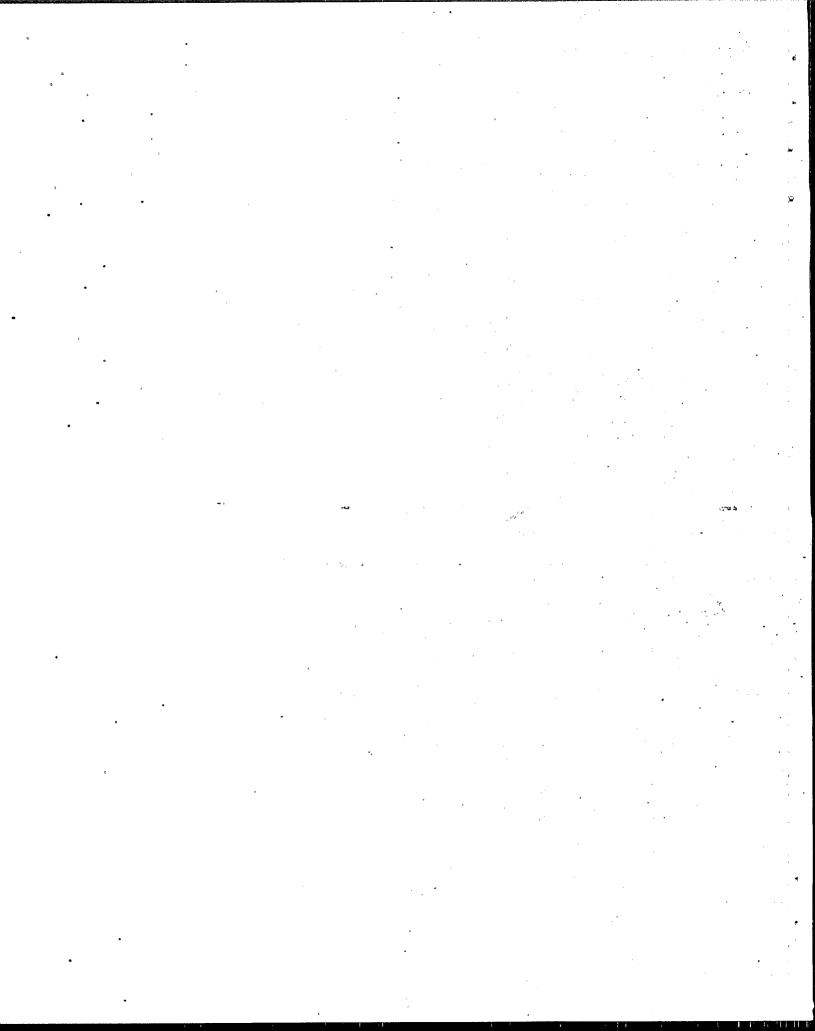
This study was completed with the assistance of a technical consultant, Louis W. Dawson, who has more than 30 years of experience in major appliances—primarily in refrigerator manufacturing.

General Electric Appliances (GEA) provided samples of 18 cubic foot refrigerator cabinets and liners and samples of prototype VIPs. Refrigerator specifications and cost information were made available, through a non-disclosure agreement, to support the study. Ken Downs, GEA, assisted in the development of VIP sizes and served as a sounding board as the VIP manufacturing and installation processes were developed. GEA also assisted in developing tooling costs for thick wall alternatives.

Two engineers, W. Robert Keelen and Richard Muse, from the University of Kentucky (UK) Center for Robotics and Manufacturing Systems, and with combined manufacturing experience exceeding 60 years, provided valuable assistance and input.

Stephen Poulter, a senior in the mechanical engineering department at UK, provided capable CAD assistance in preparing figures and tables.

Also, considerable technical and cost information on raw materials and manufacturing equipment was provided by many companies which are listed as references on page 75. Two companies in particular; Fres-Co System USA, Inc. (Larry Restivo) and Degussa Corporation (Roger Caffier & Nick Ludovic) were especially helpful in providing key inputs.



INTRODUCTION

The construction of a typical U. S. refrigerator consists of a thermoformed plastic inner liner and a steel outer case with CFC blown polyurethane foam insulation in between. The doors usually are of similar construction. Two technologies, vacuum insulation panels (VIPs) and thicker foam insulation, have been proposed to reduce the thermal load through the refrigerator cabinet wall and the resulting power requirement.

The current design evolved from the use of fiberglass insulation during the sixties and brought significant energy efficiency improvements. The use of foam insulation allowed refrigerator manufacturers to increase the food storage capacity of a given refrigerator while maintaining the same external dimensions. This "thin wall" concept has been a key in refrigerator design. Increasing the thickness of the walls could require consumer compromises in food storage capacity for available kitchen space for consumers of larger (> 18') refrigerators.

CFCs used in the foam insulation have been banned by the Montreal Protocol and the Clean Air Act Amendments of 1990. Furthermore, President Bush has mandated that their use be completely eliminated after 1995.

The Department of Energy (DOE), authorized by the National Appliance Energy Conservation Act (NAECA) of 1987, has issued stringent refrigerator energy standards to be met for 1993 production. These standards require, on the average, a 30 percent additional efficiency increase over 1990 requirements; and possible further efficiency increases for 1998.

Many technologies can be used to reduce the energy consumption of refrigerators. Improvements can be made to the hermetic system, control systems, such as the defrost system, and components, such as fans, or to the cabinet enclosure. Improvements to the cabinet are limited to increases in thermal resistance through better gaskets, increased insulation, or lower thermal conductivity insulation. Insulation like VIPs would enhance thermal resistance without adversely affecting the internal volume to external dimension ratio.

While buyers of smaller capacity units (<21') may be willing to accept some compromises to avoid additional cost, buyers of larger units are more likely to pay a premium to preserve food storage capacity. The need to maintain this "thin wall" concept while meeting new, regulatory, refrigerator energy efficiency standards and other future requirements for energy efficiency improvements without CFCs may necessitate the use of new thermal insulation technologies.

One approach to improved thermal insulation is the use of vacuum insulation panels in conjunction with a non-CFC blown foam. These panels may be manufactured by filling a porous bag with a micro-grained powder, placing the bag into an envelope impervious to water and gases, and evacuating and sealing the envelope. The evacuated space provides a barrier to the transfer of heat which is more effective than any modern day insulation. These panels have about 67% lower thermal conductivity than CFC blown foam (Figure 1).

Research and development on vacuum panels has gone on for several years but the feasibility and cost for actual production and application continues to be debated. Other important issues such as the long term degradation of the vacuum and the impact of CFC substitutes, are being addressed elsewhere.

This study evaluates the manufacturing feasibility and estimates cost to produce and install vacuum insulation panels into refrigerators. It also estimates the manufacturing and product costs of adding more foam to thicken the urethane foam insulation.

Figure 1 Equivalent Insulations K=BTU-IN/HR-FT2-°F

	K = 0.240
6" Fiberglass	
	K = 0.120
3" Urethane Foam	
1" Vacuum Insulated Panel	K = 0.040

FINDINGS

- It is feasible, with existing technology, to manufacture vacuum insulation panels
 (VIPs) in sufficient volume and with sufficient quality for installation into household refrigerators.
- Existing refrigerator plants can be retrofit to install VIPs but may require significant rearrangement and cost.
- This technology will allow significant reduction in refrigerator energy usage without increasing the external dimensions of the refrigerator.
- Replacing urethane foam with VIPs will significantly increase the variable manufacturing cost and thus the retail price of refrigerators. The increase in variable manufacturing cost of the refrigerator is estimated to be \$1.39 per board foot of VIPs or about \$40 for a 21 cubic foot refrigerator. This would translate to about \$120 higher retail cost. This cost can probably be reduced through optimization of silica processing steps between silica manufacturing and VIP manufacturing. Also, other filler materials, such as aluminum silicate, in place of or in combination with precipitated silica may prove more cost effective. A goal of \$1.00 per board foot is probably attainable within three to five years of initial production.
- Investment and expense required to implement the production and application of VIPs for three hundred thousand 21 or 24 cubic foot refrigerators per year is estimated to be about \$24 million. This cost can probably be reduced by optimization of the flash drying and densification processes between the VIP plant and the silica plant. Increased costs to the consumer will be minimized if the total systems cost, from the manufacture of silica to the final panel installation, is optimized.
- As the cost of urethane foam increases, the cost difference between foam and VIPs
 will decrease by about \$0.02/board foot for every 10% increase in foam cost. This

assumes that VIP cost will remain the same although a decrease is likely as the manufacturing process is optimized.

- Thicker foam insulation is a viable alternative on smaller models (<18') where kitchen installation dimensions are less limiting. Maintaining the same approximate height: width: depth ratios will be necessary to avoid significant kitchen fit problems (reduced market) when adding more insulation.
- Adding VIPs will not increase refrigerator shipping cost because even with the added
 weight of VIPs, the weight of a 48 foot trailer remains less than one half the gross
 weight limit. Shipping cost will increase for thicker insulation, even with a one half
 inch increase in insulation thickness, because the number of refrigerators per trailer
 will be reduced.
- The product and transportation cost increase to add one inch of foam to an 18' cabinet will be about 50% of the cost of adding vacuum insulation panels to a 21' cabinet and will give comparable energy improvement.

RECOMMENDATIONS

- 1. A prototype facility should be built by an appliance manufacturer or an independent company to develop and optimize VIP manufacturing. A joint venture with either a silica manufacturer or a form, fill, and seal equipment manufacturer is an alternative.
- Long term vacuum and insulation degradation should be evaluated via accelerated life
 tests and field trials, so that refrigerator life cycle benefits and liabilities (in warranty
 and out of warranty costs) are better understood.

GENERIC REFRIGERATOR ASSEMBLY LINE

As a basis for this study a generic refrigerator line and factory has been defined. Product assumptions for this line are:

- 1. Three cabinet sizes may be produced: 18 cubic foot, 21 cubic foot and 24 cubic foot.
- 2. Steel case and plastic liner construction. Steel doors also have plastic inner liners.
- 3. Urethane foam insulation in both the cabinet and door.
- 4. Foam blowing agent will be R-ll or a suitable substitute. Foam, in conjunction with vacuum insulation panels, will provide a mechanical structure equivalent to the current design.
- 5. Product redesign changes to accommodate VIPs will be minimal.

- Process assumptions are:

- The fabrication and assembly line will operate two 7.6 hour shifts, five days/week,
 220 days/year.
- 2. The line will produce one unit every 20 seconds.
- 3. At 85% efficiency the line will have a capacity of about 500,000 units per year. (180 units/hour \times 7.6 hours/shift \times 2 shifts/day \times 220 days/year \times .85)
- 4. Output will average 1,163 units per 7.6 hour shift.

The areas of the plant which are examined in this study are case and liner pre-foam and door pre-foam. The case and liner pre-foam area is shown in Figure 2. The door pre-foam area is shown in Figure 3.

The layouts of the affected areas will be different in each refrigerator plant and the actual rearrangement and costs required to install VIPs will vary from this study and from one manufacturer to another.

Figure 2
Case and Liner Pre-foam Areas

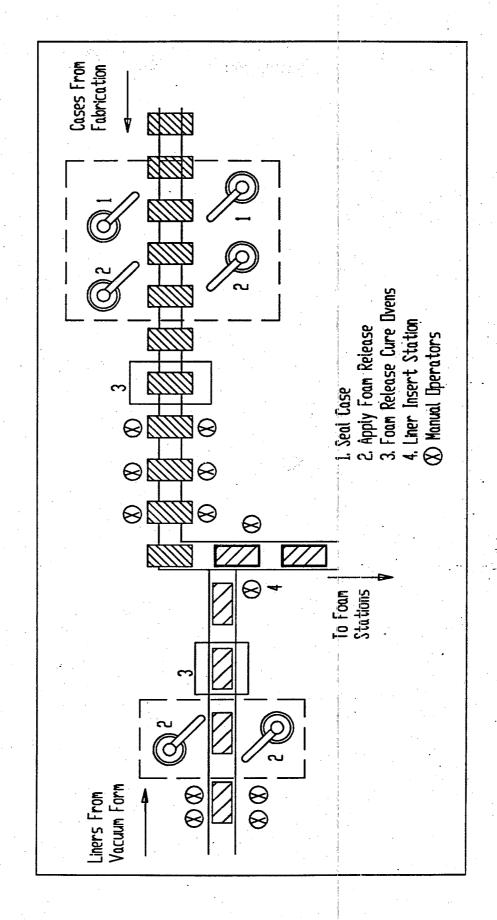
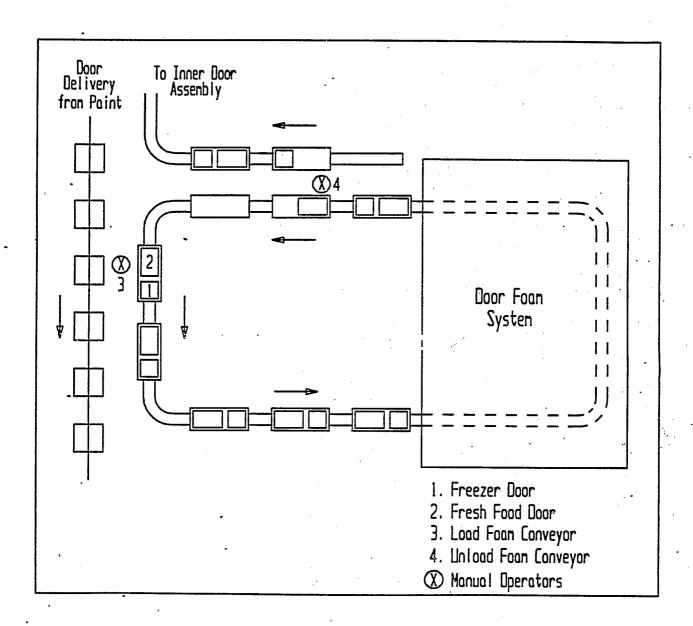


Figure 3 Door Pre-Foam Area



VACUUM INSULATION PANEL REQUIREMENTS

This study assumes that all 21 and 24 cubic foot refrigerators made on this generic line will receive vacuum insulation panels and the total annual volume of these models is 300,000 per year. Eighteen cubic foot models are not included since this size is more price sensitive and would be less likely to use VIPs. A thicker insulation alternative for smaller, more price sensitive models is discussed in "Thick Wall Alternatives".

All of the 21 and 24 cubic foot models will be produced on the line with an annual capacity of 500,000, thus using 60% of that line's capacity. The other 40% would be used for 18' models. When running models with vacuum insulation panels, the 20 second cycle time will still be maintained.

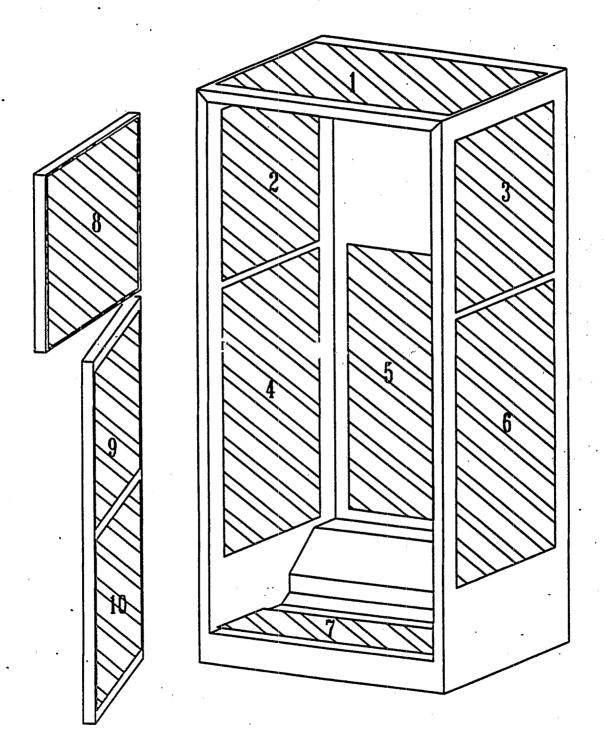
It is assumed that the refrigerator line will schedule the models which will receive VIPs an equivalent of three days or six shifts each week, or a maximum of 6,978 refrigerators with VIPs per week. These models normally will be 60% of each day's production or 1,396 per day on two shifts, but sufficient in-process storage is provided to support a continual two shift run.

Both cabinet sizes use the same set of panels, giving slightly less coverage for the 24 foot as a trade off for increased manufacturing efficiency in the panel plant. The 18 foot model also could use these same panels. As the volume of models with VIPs increases, justifying a second panel line, panel sizes could be further tailored to specific models to attain greater energy improvement.

Through analysis of an actual 18 cubic foot cabinet, optimum panel locations and sizes were developed. All of these panels would, of course, fit into a 21 cubic foot and a 24 cubic foot cabinet since all of the dimensions are the same or slightly larger. A 21 cubic foot refrigerator with VIP locations is shown in Figure 4.

Figure 4 Refrigerator Panel Locations

21ft³ Refrigerator with 10 Panels



There are ten panels in each refrigerator. The panels will be produced in five sizes with two thicknesses (1/2" & 1") and two lengths (21" & 28"). Table 1 shows the panel dimensions for each location and the installation area where they would be attached. Table 2 shows the sizes for the barrier and porous pouch material required to produce the five panel sizes in the panel plant.

A panel was not planned in the freezer back because interference with the suction line, ice maker fill tube, and air flow duct necessitated a small panel which was deemed ineffective. A product redesign to relocate some of these could allow a freezer back panel to be large enough to be justified.

Table 1
Vacuum Panels for 21' & 24' Refrigerators

PANEL#	SIZE (INCHES)	LOCATION	INSTALLATION AREA
. 1	1×21×28	Freezer Top	Case Pre-Foam
2 & 3	$1 \times 21 \times 19$	Freezer Sides	Case Pre-Foam
4 & 6	$1 \times 21 \times 30$	Fresh Food Sides	Case Pre-Foam
rv.	$1 \times 21 \times 28$	Fresh Food Back	Liner Pre-Foam
7	$0.5 \times 28 \times 10$	Fresh Food Bottom	Case Pre-Foam
∞ ,	$0.5 \times 28 \times 19$	Freezer Door	Door Pre-Foam
9 & 10	$0.5 \times 28 \times 19$	Fresh Food Door	Door Pre-Foam

Total area of panels = 35.5 square feet Total weight of panels = 29 pounds Total board feet = 29

Table 2
Vacuum Panels for 21' & 24' Refrigerators
MATERIAL SIZE (Inches)

MATERIAL SIZE WITH FLANGES	UCH BARRIER	(+2.0")	5 23×30	5 23×21	5 23×32	(+1.5")	29.5 x 11.5	29.5 × 20.5	5971.5	8
MATERI	POROUS POUCH	(+1.5")	22.5 × 29.5	22.5 × 20.5	22.5 × 31.5	(+1.0")	29 x 11	29 x 20	5726.5	79.5
	SIZE (Inches)		1×21×28	1×21×19	$1 \times 21 \times 30$.5 x 28 x 10	.5 x 28 x 19		feet \times 2 (top & bottom)
	PANEL #		1&5	2 & 3	4 & 6		7	8,9 & 10	Total square inches	Total square feet \times 2 (top

VACUUM INSULATION PANEL MANUFACTURING

This section describes the facility, organization, materials, and equipment required to produce three million VIPs per year for three hundred thousand 21 or 24 cubic foot refrigerators.

When selecting the location for the facility with regard to the appliance assembly plant, several elements must be considered. Raw material sources and transportation, the possible requirement to make VIPs for multiple assembly plants, and the trend away from vertical integration and toward "assembly only" plants are all items which must be factored into this decision.

Materials for VIPs were selected from those currently being used for R & D, and costs were obtained from the materials manufacturers or their representatives.

The VIP manufacturing process was defined and the equipment selected after numerous discussions with several parties who have produced VIPs for R & D; manufacturers of form, fill, and seal equipment who incorporate vacuum packaging in their equipment; users of form, fill, and seal equipment for vacuum packed products such as coffee; manufacturers of silica and bag materials; and many equipment manufacturers who supply equipment which has the capability to perform portions of the VIP manufacturing process.

Some equipment manufacturers whose equipment was considered but not included in the final design are included in the references.

VIP manufacturing is discussed in the following sections.

- A. Facility and equipment
- B. Panel plant organization and operation
- C. Silica material
- D. Bag materials
- E. Silica material handling

- F. Flash drying
- G. Silo storage
- H. Densifying
- I. Bag filling
- J. Panel manufacturing line
- K. Quality control
- L. Packaging
- M. Bar coding
- N. Shipping and transportation
- 0. Safety and environmental considerations

A. Facility and Equipment

It was assumed that the panel plant would be built 100 miles from the refrigerator plant and next to the silica plant, and that the silica plant would be next to the silicate plant. Sodium silicate and sulfuric acid are the raw materials for the production of precipitated silica. A major consideration for the location of the complex would be transportation means and routes for sand and soda ash, which are the raw materials for sodium silicate.

About three pounds of sodium silicate are required to produce one pound of silica. Silica is transferred to the VIP plant at about four pounds per cubic foot and completed VIPs are about 12 pounds per cubic foot. These ratios suggest that shipping VIPs may be less expensive than shipping silica or its raw materials.

The building would be sized to accommodate three panel lines for future expansion to ten million panels (one million refrigerators) per year. Cost for only one panel line and supporting equipment is included in this study. Building cost was estimated based on actual cost of a recent plant and includes normal power distribution, lighting, offices, heating and air conditioning, and other utility equipment plus truck docks, parking lot, landscaping, roads, etc.

The building would be air conditioned to provide the required humidity control as well as employee comfort. There would be one sheltered, two trailer receiving dock and one sheltered, two trailer shipping dock. A layout of the panel plant is shown in Figure 5.

The panel plant equipment, which will be discussed in detail later, is summarized in Table 3, along with the estimated costs. A 25% contingency, commonly used by manufacturers for feasibility study estimates, has been included.

B. Plant organization and operation

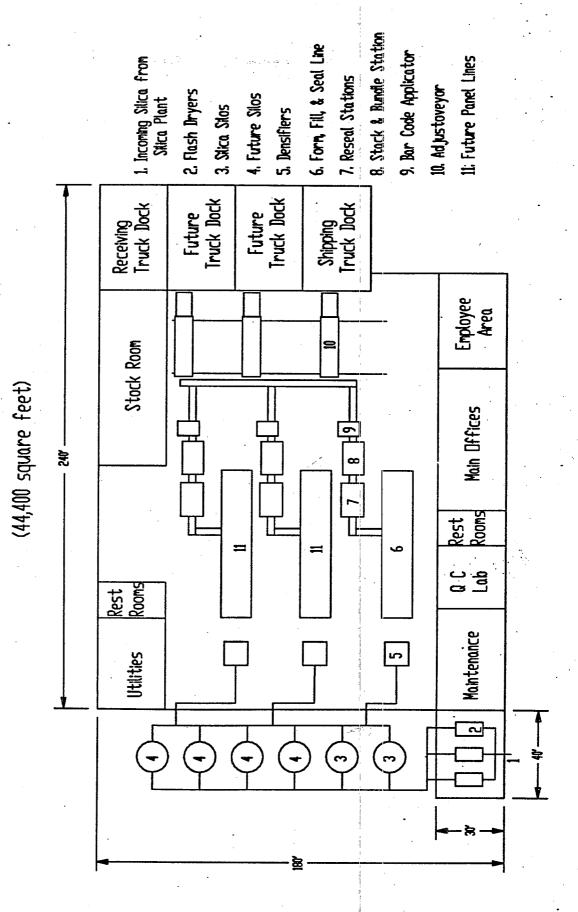
The plant will have nine salaried and 22 hourly personnel, as shown on the organization chart in Figure 6. Hourly personnel will be paid on a day work plan. Position descriptions for all personnel will allow them to do any job which they are capable of performing. Cross training and job flexibility will be rewarded with higher hourly rates.

Quality control personnel will be responsible for inspection work as well as quality engineering and process cor irol. Foremen will be responsible for process control and have dotted line responsibility to the quality control manager. The quality control manager will also be responsible for safety and OSHA compliance.

Machine control personnel will be responsible for set-up, machine control, process control, loading material on and off equipment, minor maintenance and unjamming, preventive maintenance, and housekeeping in their area.

Shipping material handlers will be responsible for loading trailers and keeping the line stocked with material, which will be done primarily during changeovers. Three operators are planned on each shift so that adequate relief to trailer loaders can be provided by assignment rotation. Panel plant operating personnel and costs are summarized in Table 4.

Figure 5
Panel Plant Layout



EQUIPMENT	NUMBER	VENDOR	CO." "/UNIT	TOTAL	SHIPPING	INSTALLATION	TOTAL COST
Silos	7	Peabody	\$50,000	\$100,000	\$3,000	\$8,000	\$111,000
Pneumatic system		Roessler		210,000	2,500	21,000	233,500
Flash dryer	-	Aljet	440,000	440,000	8,800	44,000	492,800
Densifier	-	Aljet	200,000	200,000	4,000	20,000	224,000
Auger filler	—	Mateer-Burt	, 15,000	15,000	450	3,000	18,450
Form, fill, and seal	-	Fres-Co	5,000,000	5,000,000	150,000	1,000,000	6,150,000
Hot bar reseal	~	Fres-Co	20,000	50,000			20,000
Vacuum check	-	Taptone	25,000	25,000	250	2,000	30,250
Bundle stacking	(—1	Zellerbach	50,000	50,000	1,000	5,000	26,000
Auto pack		Zellerbach	. 13,000	13,000	100	1,300	14,400
Bar code	_	Zellerbach	21,000	21,000	200	1,000	22,500
Adjustoveyor	-	Stewart Glapat	50,000	20,000	\$2,000	\$2,000	54,000
Tractors	7	Kenworth	000'09	120,000	N/A	N/A	120,000
Trailers	9	Dorsey	16,000	000′96	N/A	N/A	000'96
QC lab equipment		Various	e per	100,000			100,000
Maintenance equipment		Various	<i>.</i>	20,000			20,000
Fork/coil truck	-	Clark	40,000	40,000			40,000
Spare parts		5% of selected eq.		250,000			250,000
Building		44,400 sq. ft.	\$85/sq. ft.	3,774,000	·		3,774,000
Land		•	•	100,000			100,000
Office equipment				\$25,000			\$25,000

Total equipment cost Contingency 25% Total with contingency

\$12,011,900 3,002,975

\$15,014,875

Figure 6 Panel Plant Organization

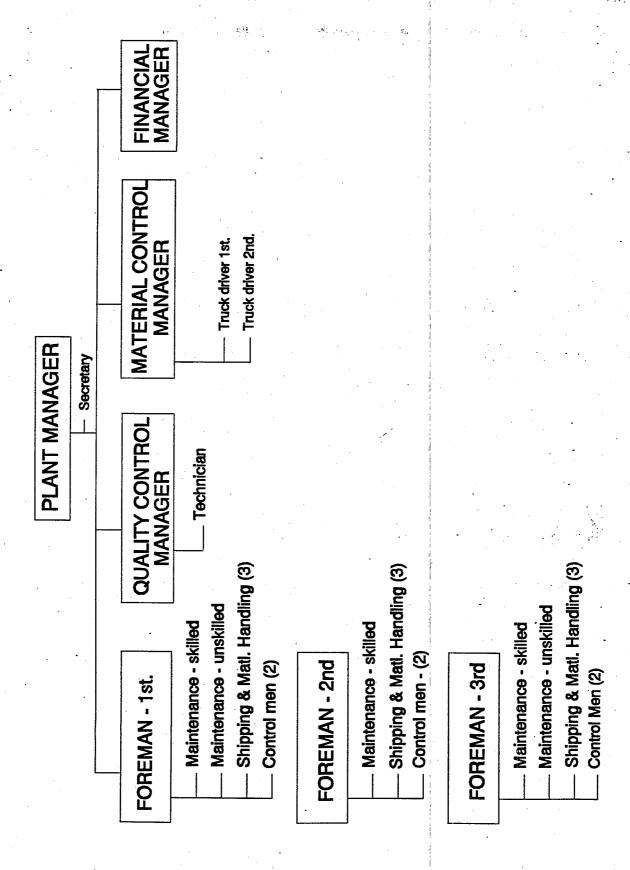


Table 4
Annual Operatiry Cost – Panel Plant

	NUMBER	HOURLY RATE	ANNUAL WAGE	BENEFITS	OVERHEAD	ANNUAL COST
SALARIED PERSONNEL				(40%)	(140%)	
Plant manager	⊣		\$40,000	\$16,000		\$56,000
Financial manager	-		30,000	12,000		42,000
Quality control manager	-		30,000	12,000		42,000
QC technician	1		20,000	8,000		28,000
Foreman	က		25,000	10,000		105,000
Material control	 1		20,000	8,000		28,000
Secretary	 1		16,000	6,400		22,400
Total Salaries						323,400
HOURLY PERSONNEL						
Maintenance-skilled	က	\$15.00	31,200		\$43,680	224,640
Maintenance-unskilled	7	8.00	16,640		23,296	79,872
Shipping and materials handlers	.0/	8.00	16,640		23,296	359,424
Control men	9	12.00	24,960		34,944	359,424
Total Hourly Wages	·		. ,			1,023,360
TRANSPORTATION COST						
Truck drivers	2	\$15.00	\$31,200	1144	\$43,680	149,760
Truck operation						48,000
Total Transportation Costs				-		197,760
OTHER OPERATING COSTS		-	- ,		,	267,280
TOTAL PLANT OPERATING COST						\$1,811,800

C. Silica material

The silica used for filling the panel is FK500LS, supplied by Degussa [4]. A product information sheet is shown in Appendix A. Material cost is assumed to be \$0.75/pound, as stated in a letter from Degussa (formerly North America Silica) to Mr. Alan Fine, EPA, on June 11,1991 (Appendix B).

Flash drying and densifying equipment provided in this plant would most likely facilitate the use of a less expensive silica with a larger particle size and higher moisture content. Thus, it may prove feasible to start with a less expensive silica by doing further processing in the panel plant. Whether or not this is feasible would have to be determined through R & D and pilot operations where trade-offs between panel unit cost and insulation efficiency could be evaluated.

D. Bag materials

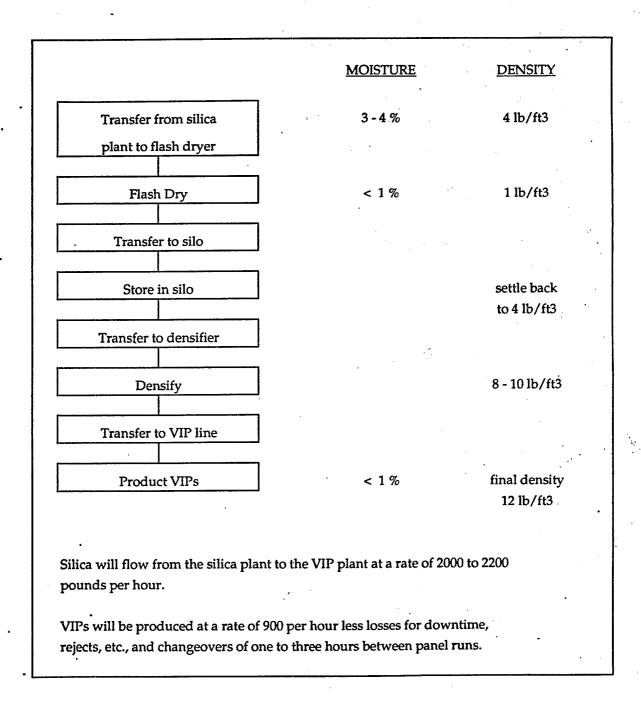
The microporous bag, which will contain the silica during compaction and evacuation, is TYVEK supplied by Snow Filtration, Cincinnati, Ohio [23]. This material is quoted at \$0.036/ square foot in the volumes assumed for this study.

The barrier bag, which retains the vacuum, is VECAT. A multi-layered material supplied by Fres-Co System USA, Inc., Telford, Pa.[l]. It is quoted at \$0.111/square foot at the volumes assumed for this study.

E. Silica material handling

Silica is transferred by a Vac-U-Max pneumatic system (Roessler) [9] from the silica plant, assumed to be adjacent to the panel plant, into a flash drier located in the panel plant and then into a silo, as shown in the flow chart in Figure 7. Silica coming into the panel plant has an average particle size of 3.5 microns, a density of four pounds per cubic foot, and a moisture content of 3–4%.

Figure 7 Silica Processing Flow Chart



Silica usage will average 16,000 to 18,000 pounds per eight hour shift (see Table 5). Maximum usage with the line operating at 100% efficiency, no changeovers and producing the largest panel (#4 & #6) will be 31,536 pounds per eight hour shift.

F. Flash Drying

Silica coming into the panel plant from the silica plant would first be processed through a flash drier before entering a silo.

Experimental panel manufacturing processes have dried the silica in an oven after it has been put into the porous bag. This process is acceptable for R & D but was judged too expensive for high volume production.

The flash drier is designed to reduce the moisture content of the silica from 3 to 4% to less than 1%. The equipment selected for this application is a Jet-O-Drier® produced by Fluid Energy Aljet [6]. The Jet-O-Drier is a flash/spray drier with a material retention time of less than one second. This equipment can accommodate very high inlet temperatures without causing product degradation while still maintaining a low outlet temperature.

Aljet's description of the Jet-O-Drier operating principle is:

"Drying gas, usually air, is pressurized, heated, and introduced into the Jet-O-Drier by specially designed nozzles. The energy of the pressurized hot fluid (or wet powder) is converted into velocity. The directional flow from the nozzles develops a controlled high velocity drier circuit. The system velocity is balanced by mass flow and evaporative rate which maintains a system pressure inside the drier slightly above atmospheric. Wet solids are introduced pneumatically or by means of a rotary vane. The violent action in the drying chamber deagglomerates the individual particles, thereby exposing enormously large drying surfaces. At the drier outlet the finely dispersed dry particles are removed by the frictional drag of the exhausting gases and the heavier moist particles are returned to the drying chamber due to their higher momentum."

Average Silica Use Per 8 Hour Shift @ 85% Efficiency on Panel Line

PANEL #	LBS./PANEL	PANELS/8 HRS.	TOTAL WEIGHT (LBS.)
1	4.08	612	2497
2	2.77	612	. 1695
: m	2.77	612	1695
4	4.38	612	2681
ıc	4.08	612	2497
9	4.38	612	2681
7	0.97	612	594
∞	1.85	612	1132
6	1.85	612	1132
10	1.85	612	1132
Totals	28.98	6120	17736

NOTE

- 1. 17,700 lbs./shift @ 4 lbs/ft3 = 4,430 ft3/shift or about 0.6 silos
- 2. Actual silica use per shift will vary from 5900 lbs (panel #7) to about 30,000 lbs (panel 4&6) depending on which panels are being run.

Immediately after being processed through the flash drier the silica would have a density of about one pound per cubic foot. It would redensify to about four pounds per cubic foot as it settled in the silo. Air would be removed from the top of the silo to speed up densification.

Figure 8 shows a typical Jet-O-Drier system.

G. Silo storage

Two silos will be used; one will receive incoming silica from the flash drier while the other dispenses silica to the panel manufacturing process. Each silo will be 71 feet high and 14 feet in diameter with a 60 degree hopper. Silos are aluminum with welded construction, manufactured by Peabody TecTank [17] (Appendix C).

With a ten foot head clearance, each silo has a capacity of 7000 cubic feet (28,000 pounds @ four pounds per cubic foot). One full silo will support about eight hours of production on the form, fill, and seal line when producing the largest panel size (l"x28"x30") at 85% efficiency. Changeover from silo to silo will be simple and quick through the use of electronically controlled, rotary actuated valves. Silos will be piped so they can be filled from any of the flash driers and can feed any of the densifiers.

Table 6 shows that starting with one full silo and using the scheduling plan shown in Table 7, two silos are adequate to accommodate a continuous flow of silica from the silica plant. The maximum silica inventory reaches 39,040 pounds at the end of the panel 8, 9 and 10 run and drops to a low of 14,816 pounds at the end of the panel 1 and 5 run. Two silos will hold 56,000 pounds of silica at the planned density of four pounds per cubic foot.

H. Densifying

Silica will flow from the silo into a densifier by means of a pneumatic transfer system. The densifier will increase the silica density to 8–10 pounds per cubic foot.

Figure 8 Jet-O-Drier Flash Drier

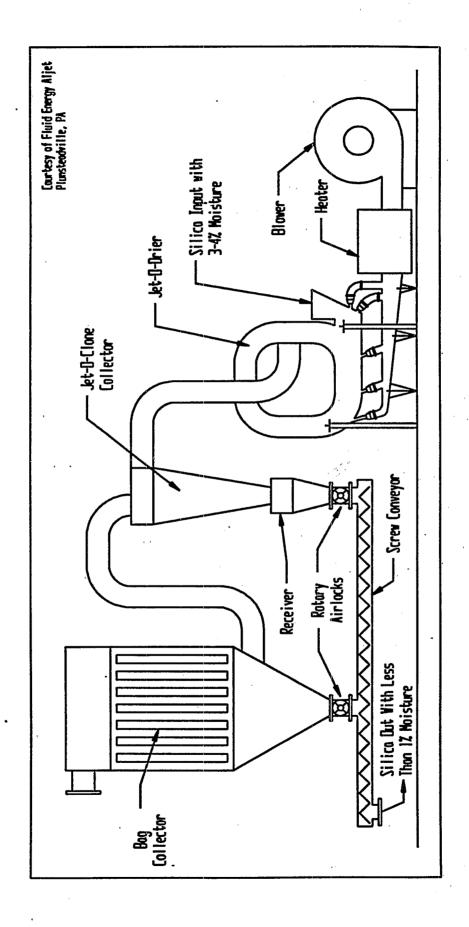


Table 6
Silica Silo Inventory
(@ 900 Panels/hour and 2024 Lbs/hour from Silica Plant

		.*																				;		low								:		
INVENTORY	36695	36226	35757	35288	37312	39336	37418	35500	33582	31664	29746	27828	25910	23992	26016	28040	26392	24744	23096	21448	19800	18152	16504	14856	16880	18904	20055	21711	23367	25023	26679	28335	29991	31647
Lbs. OUT	8676	2493	2493	2493	changeover	length	3942	3942	3942	3942	3942	3942	3942	3942	changeover	length	3672	3672	3672	3672	3672	3672	3672	3672	changeover	width & thickness	873	873	873	873	873	873	873	873
Lbs. IN	2004	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2529	2529	2529	2529	2529	2529	2529
PANEL NUMBER BEING PRODUCED (WEIGHT)							4 &c 6	(4.38 LBS.)		-						•	1&5	(4.08 LBS.)				4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4					^	(0.97 LBS.)	:		•			•
								low												i Z				,						high	,	•		-
INVENTORY	28000	24704	23056	21408	19760	18112	16464	14816	16840	18864	20015	21166	22317	23468	24619	25770	26921	28072	30006	32120	32479	32838	33197	.33556	33915	34274	34633	34992	37016	_		38102	37633	37164
Lbs. OUT	3672	3672	3672	3672	3672	3672	3672	3672	changeover	width & thickness	873	873	873	873	873	873	873	873	changeover	width	1665	1665	1665	1665	.1665	1665	1665	1665	changeover	length & thickness	2493	2493	2493	2493
LbsS. IN	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024
PANEL NUMBER BEING PRODUCED WEIGHT)	16.5	(4.08 LBS.)								-	7	(0.97 LBS.)					-				8, 9, & 10	(1.85 LBS.)				•					2 & 3	(2.77 LBS.)		

Form, Fill, and Seal Line Changeovers and Scheduling

				Z	UMBER OF DI	MENSIONS CF	NUMBER OF DIMENSIONS CHANGED WHEN	7
PANEL NOMBEK		DIMENSIONS			CHANGII	CHANGING TO PANEL NUMBER	NUMBER	
-	LENGTH	WIDTH	THICKNESS	7	8, 9, & 10	2 & 3	4 & 6	1 & 5
නී ව	28	21	qued ,	.	2	· , , , ,	+- 1	
	28	10	1/2		1	e	ю.	. 2
8, 9, & 10	. 58	19	1/2	-		2	က	2
2 & 3	21	19		က	2		I	
4&6	30	21	1	3	က			-

Fluid Energy Aljet builds a VACUPRESS densifier designed to increase the densities of very fine powders (finer than 40 microns) where their high air content hinders further processing [6].

Aljet 's description of the VACUPRESS operating principle is:

"The densifying effect is achieved by a combination of vacuum and mechanical pressure. The VACUPRESS process is achieved by means of two drums turning in opposite directions, designated filter drum and pressure drum.

[Figure 9]

"The product to be densified encloses the filter drum and thereby allows the filter or de-aeration action to take place. As the drum revolves, the particles rearrange to form by vacuum effect a continuous layer on the surface of the filter drum and pre-densify by the exhausting air passed through. The layer of de-aerated powder passes through the gap between the filter and pressure drums where it is subjected to a preselected rolling pressure. The rolling pressure action brings the de-aerated powder particles closer together as dense powder or soft agglomerates. Afterwards, the densified product is continuously stripped off the filter drum up to the filter layer and leaves the machine."

A typical VACUPRESS installation is shown in Figure 10.

I. Bag filling

Dry and dense silica at eight to ten pounds per cubic foot and less than one percent moisture is transferred from the densifier into an auger feeder via a pneumatic conveying system.

The microprocessor-controlled auger feeder measures and feeds a volumetric fill for each panel size. Different weights for different panel sizes are held in the feeder memory and

Figure 9
Vacupress Densifier

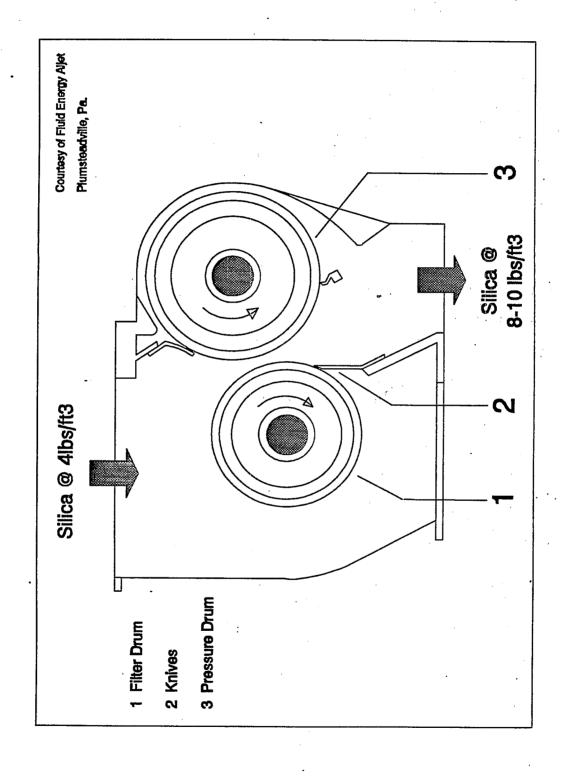
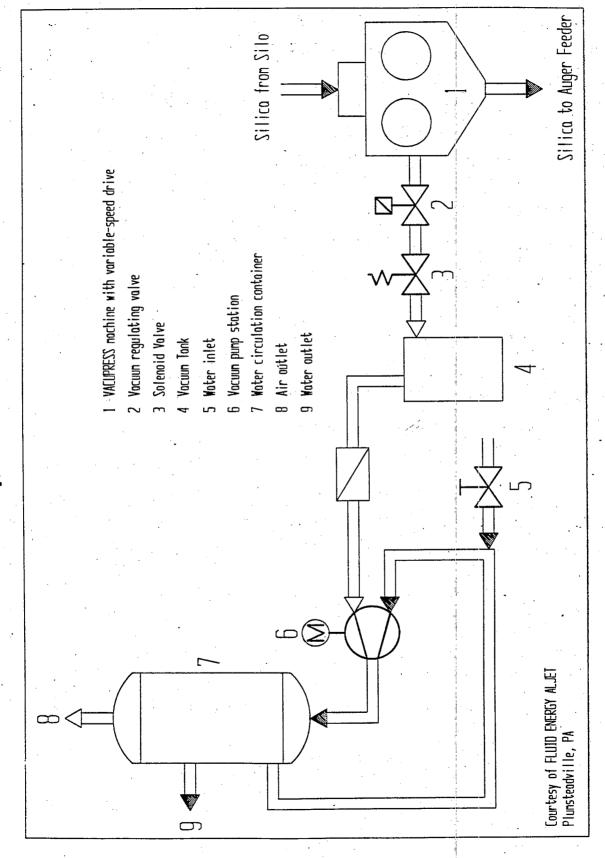


Figure 10 Vacupress Installation



changed with the push of a button. Fills for each panel are controlled to plus or minus a few grams. Five different fills are required for the panels used in this study. Change over would be instantaneous.

A Mateer-Burt Neotron System Series 1900 (Appendix D) was selected for this application [3]. The 1900 is designed for application on automatic form, fill, and seal machines and has an accuracy of plus or minus two to three grams.

J. Panel Manufacturing Line

The auger filler feeds a vertical form, fill, and seal machine which bags the silica in a porous bag [1]. The machine then places the porous bag into a multi-layer plastic bag which is inserted into a vacuum chamber where it is evacuated and sealed. Process specifications for the form, fill, and seal line are shown in Figure 11.

Horizontal equipment could be used and should be reviewed further before discounting it [2]. Also, some other types of equipment can vacuum form the barrier bag into a tray. This could be an advantage, but was not considered because it was felt that the multi-layer barrier bag could not be vacuum formed without destroying its integrity. This capability should be investigated further before ruling it out. Vertical equipment was assumed to be best suited for manufacturing VIPs.

Figure 11

Process Specifications- Form, Fill, and Seal Line

Equipment operation sequence:

- form porous pouch
- fill with silica
- lay pouch down
- vibrate flat
- compress
- form barrier bag around porous pouch
- seal on three sides and tack on forth
- cut apart
- insert bag into vacuum chamber
- compress at controlled vacuum
- seal forth side
- remove panel from chamber
- 1. Fully automatic
- 2. Cycle time—4 seconds
- 3. Evacuation time—5 minutes
- 4. Vacuum—1 millimeter of mercury (1 Torr)
- 5. Maximum panel size—l"x 21"x 30"
- 6. Semiautomatic changeover for thickness and length
- 7. Capability for two thicknesses (0.5" & 1.0"), and two lengths (21" & 28")
- 8. Five pounds maximum fill
- 9. 85% efficient
- 10. Reject rate < 1% at steady state
- 11. Materials: porous bag—Snow Filtration TYVEK barrier bag—Fres-Co VECAT silica—Degussa-FK 500LS

Form, fill, and seal machines have long been used in the food industry for vacuum packed products such as coffee, and are a proven technology (Appendix E). Although VIPs are somewhat larger than the typical food package, it is felt that these machines can be designed to produce them. Form, fill, and seal machines typically run from 80 to 100 pieces per minute. The VIP process will run only 15 panels per minute. Figure 12 shows the layout of a form, fill, and seal machine for food packaging.

The process sequence in the form, fill, and seal machine for VIPs would be:

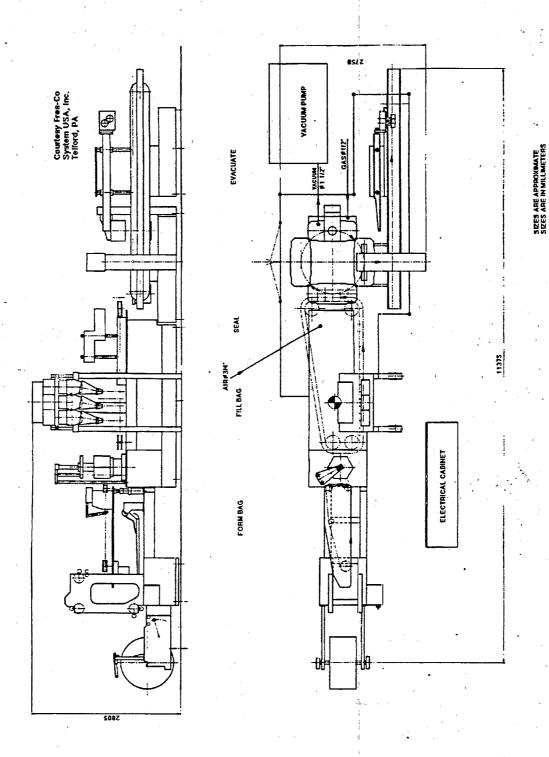
- Station 1 Form porous bag, seal bottom, fill with silica, seal top (which is bottom of next bag), cut off and drop on belt conveyor. The bag is formed as a continuous tube which is filled by the volumetric auger filler. The tube is sealed at selected dimensions by a resistance heated hot bar and cut off by a shear.
- Station 2 Locate bag, vibrate to level silica and press to compact.
- Station 3 Form barrier bag around porous bag, seal on three sides and tack of fourth side.
- Station 4 Load and unload evacuation chambers. Four panels per chamber.
- Station 5 Evacuation. Inside each chamber the control sequence will be: a. compress at a controlled vacuum; b. secondary vacuum; c. final compression; d. final vacuum; e. seal fourth side; and f. exit chamber.

There are 26 vacuum chambers and 20 vacuum lids on the line. With four panels per chamber, five and one-third minutes of evacuation will occur for each panel at the four second line cycle.

- Station 6 Secondary seal all four sides of barrier bag—three hot bar hits per side.
- · Station 7 Transfer to belt conveyor.

Changeovers from one size panel to another will necessitate changing porous bag and barrier bag material sizes, changing mandrel for porous bag forming, adjusting both bag stations, adjusting compression stations outside and inside vacuum chambers when a

Figure 12 Form, Fill, and Seal Line



thickness change is made, and adjusting hot bar sealers. It is estimated that changeovers will take from one hour for a one dimension change to three hours for a three dimension change.

The line can be scheduled so that there are no three dimension changeovers. The best run sequence which requires two one dimension changes and only three two dimension changes is shown in Table 7. Planning run and changeover sequence will reduce overall setup time which is the major component of efficiency loss. The line normally will run each panel for eight hours and then change to another. This plan will produce a maximum of 7200 panels on each run, i.e., one week's requirement for one panel for the refrigerator plant (6980 units/week).

· With a five day, 24 hour work week, this schedule allows 80 hours per week for production (10 panels x 8 hours per panel), 20 hours for changeovers (10 changeovers x 2 hours average time per changeover), and 20 hours for maintenance, downtime, and other losses.

Table 7
Form, Fill, and Seal Line
Changeovers and Scheduling

				Z	UMBER OF DI	MENSIONS CF	NUMBER OF DIMENSIONS CHANGED WHEN	Z
PANEL NUMBER		DIMENSIONS			CHANGII	CHANGING TO PANEL NUMBER	, NUMBER	
	LENGTH	WIDTH	THICKNESS	7	8, 9, & 10	2 & 3	4 & 6	1 & 5
1&5	28	21	· 🕶	2	2	-		
2	28	10	1/2		-	т	က	7
8, 9, & 10	28	19	1/2	—		2	က	2
2 & 3	21	19		m	2		-	,
4 & 6	30	21		3	3	1		1

K. Quality Control

Panels coming off the panel line would be 100% tested to determine whether or not the pressure was below an established limit. This test would be done in the four second cycle and panels without the proper vacuum would be diverted into a reject bin and an alarm would be sounded. Controls would be integrated so that the line could be shut down and a control person summoned if a panel failed the test limit.

This test would be done using a single head transducer which generates an electromagnetic impulse which then creates an audible tone. The frequency or pitch of the tone indicates the relative vacuum or pressure in the panel. A high pitch denotes high vacuum and a low pitch represents low vacuum [14].

This technology is proven, and equipment which is now being used to test vacuum bagged products is commercially available (Appendix F). Further development would be required for this specific application and for determining the actual vacuum range which could be measured.

Control operators would salvage the silica from rejected panels and take scrap bag material from the plant to an outside dumpster daily.

A quality control laboratory would perform more accurate vacuum measurements on an audit basis. Laboratory equipment would be a different type, which would allow an entire panel to be placed into a vacuum chamber which would be pulled down until an equilibrium with the internal vacuum in the panel was reached. Optic sensors would detect a slight movement of the outer panel membrane at this point.

This equipment, which would be accurate within one or two Torr, has been produced for laboratory use [16] (Appendix G). Equipment which would use only a small vacuum head placed against the panel but using the same principle is being developed at ORNL [15].

This approach could reduce the cost of laboratory equipment. Its capability to meet a four second manufacturing cycle and be feasible on a manufacturing line is yet to be established. If it should prove feasible, accuracy would probably be significantly improved over the magnetic pulse approach.

L. Packaging

Panels coming off the form, fill, and seal line every four seconds will be automatically stacked into bundles and strapped. Bundles are sized so they can be handled manually to avoid the need for skids and fork lift handling. Weights for each size bundle are shown in Table 8. A cardboard top and bottom cap will be placed on each bundle as it is stacked by an automatic stacking machine.

Each stack will be transferred automatically into a Cyklop ASM-lA (Appendix H) automatic strapping station where each bundle will be secured with two plastic straps [13]. This equipment, supplied by Zeilerbach, heat seals the strap and makes high strength seal joints which are easily removable without tools. The ASM lA is fully automatic and incorporates a powered belt conveyor and photo-electric controls.

Alternative packaging considered included shrink bundling and shrink wrap. These alternates were discarded because more dunnage would be generated at the refrigerator plant and the extra protection was not warranted since the bundles will be handled automatically or manually without fork lifts.

Bundles of panels will be transported automatically by belt conveyors to an Adjustoveyor (Appendix I) which will carry them into a van trailer where they will be unloaded and stacked manually. The Adjustoveyor will be mounted on tracks to allow it to travel between shipping docks [10].

Average Daily Panel Requirements
for Refrigerator Assembly Line
(60% of two shift production @ 85% efficiency)

PANEL#	PANELS/ DAY	PANELS/ BUNDLE	WEIGHT/ BUNDLE	BUNDLES/ DAY
1 & 5	2,792	10	40.8	280
2 & 3	2,792	15	41.6	187
4 & 6	2,792	10	43.8	280
7	1,396	40	38.8	35
8,9 & 10	4,188	20	37.0	210
Total	13,960			992

M. Bar coding

Each bundle of panels will receive a label bar code to identify the panel size and date of manufacture. Label bar coding was selected because of its superior clarity over ink jet bar coding when applied to cardboard. Labels will be printed at the line and placed on the cardboard cap of each bundle of panels automatically. Equipment selected for this application is the LPA/80T thermal label printer/applicator manufactured by Lord Label Systems, Inc. [13] (Appendix J).

N. Shipping and Transportation

Panels will be shipped to the refrigerator plant on a just-in-time basis by a captive trailer fleet. Trailers will be Dorsey vans (48'L X 8.5'W X 13.5'H) which will be retrofitted to give maximum protection to the panels. Tractors will be Kenworth T600A, fuel efficient day cabs with a five year, 750,000 mile warranty [19].

All production from the panel plan, will be loaded directly into trailers. A sufficient number of trailers is provided to store the equivalent of two shifts of production for the refrigerator plant in addition to having one being loaded and an empty standing by.

The average daily requirement for production at the refrigerator plant will be about 14,000 panels or 1000 bundles (Table 8). An average of one trailer per day will be needed to deliver this requirement (Table 9).

0. Safety and Environmental Considerations

FSK5OOLS silica is an odorless, dry, white powder. The material is completely safe to the panel plant employees. It is neither toxic nor flammable and there is no explosion hazard. Adequate ventilation is required and, where dust occurs, a NIOSH-approved dust respirator is recommended.

A Material Safety Data Sheet is shown in Appendix K.

48 Foot Trailer Loading Table 9

PANEL #	BUNDLE DIMENSION (INCHES)	LOAD PATTERN	BUNDLES/DAY REQUIRED	BUNDLES/ TRAILER	DAILY ȚRAILER REOUIREMENTS
1 & 5	23 x 30 x 10.5	4W(23") x 19L x 14H	280	1064	0.26
2 & 3	23 x 21 x 15.5	4W(23") x 27L x 10H	187	1080	0.17
4 & 6	23 x 32 x 10.5	4W(23") x 17L x 14H	280	952	. 0.29
7	30 x 12 x 20.5	8W(12") x 19L x 7H	35	1064	0.03
8, 9 & 10	30 x 21 x 10.5	3W(30") x 27L x 14H	210	1134	0.19
Total					0.95

NOTE

panels, depending on panel plant and refrigerator plant scheduling. 1. Trailer Dimensions: $98"W \times 570"L \times 156"H$ 2. Actual trailer loads would probably be made up of 1 to 3 different

PANEL INSTALLATION INTO REFRIGERATORS

This section describes the facility modifications and equipment needed at the refrigerator plant to receive, handle, and install 3,000,000 VIPs per year into three hundred thousand 21 or 24 cubic foot refrigerators. Modifications are based on generic plant assumptions and would be different for an actual plant and vary from one plant to another. Panel installation is discussed in the following sections.

- A. In-plant receiving, material handling and storage
- B. Delivery to assembly areas
- C. Adhesive application and panel insertion
- D. Quality control
- E. Foaming around VIPs
- F. Refrigerator plant equipment and incremental operating costs

A. In plant receiving, material handling, and storage

Panels would be received at two new docks in a new 9,774 square foot building addition. (Figure 13) Panels would be unloaded using an extendable adjustoveyor in reverse of the loading method at the panel plant. The adjustoveyor would feed a sortation conveyor which would feed eleven, five tier, flow-through racks which hold each of the ten panels for a refrigerator [11]. A bar code reader integrated with the conveyor controller would select a tier that was not full and divert the bundle to that tier. A second reader would divert the bundle into the proper flow-through rack. Each five tier rack would hold from 195 bundles (panel # 1,4,5 & 6) to 350 bundles (panel # 7).

The eleven lanes would hold enough panels to allow the refrigerator assembly line to run two continuous shifts of models with VIPs. (Table 10) The delivery conveyor will hold almost enough panels for another shift's run. Since the assumption is that the assembly lines would average running VIP models only six shifts per week, this is a very conservative inventory plan.

Figure 13 VIP Receiving Area - Refrigerator Plant

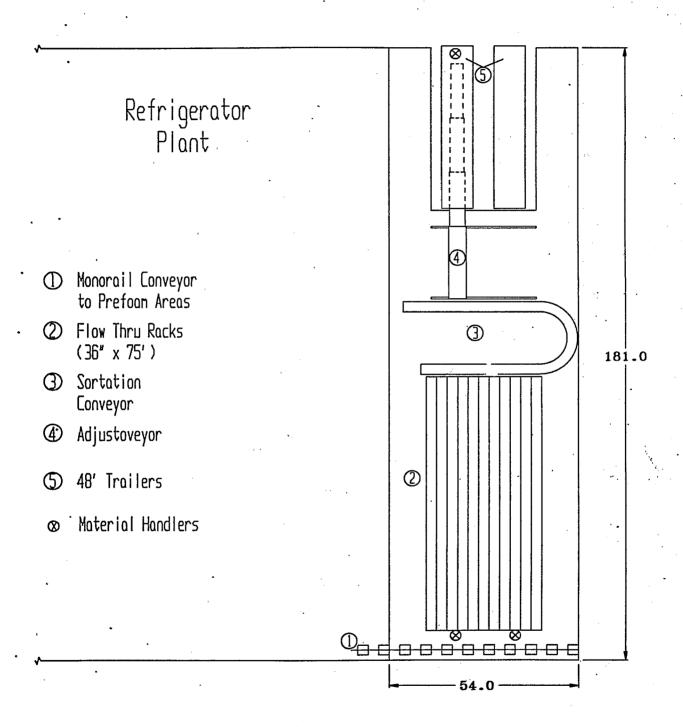


Table 10 Flow Thru Rack Requirements (Racks 32"W x 75'L x 5 Lanes High)

				BUNDLES USED	LANES	
PANEL #	BUNDLE	PANEL ORIENTATION	BUNDLES/ LANE	PER HOUR AT REFRIG. ASSY.	REQUIRED FOR 2 SHIFTS	LANES
1 & S	23 x 30 x 10.5	30"	195	36	2.8	•
2 & 3	23 x 21 x 15.5	23"	210	24	1.8	8
4 & 6	23 x 32 x 10.5	32 1 23"	195	36	2.8	m
	30 x 12 x 20.5	30"	375	6	0.4	
8, 9 & 10	30 x 21 x 10.5	30"	210	27	2.0	111

Both the sortation conveyor and the flow-through racks would be center drive belt conveyors controlled by a common controller and integrated with laser bar code readers [11].

Three hourly paid material handlers, on each of two shifts, would unload the panels from the van trailers onto the adjustoveyor and from the flow-through racks onto a continuous conveyor for delivery to the pre-foam areas.

B. Delivery to assembly areas

Four options were considered to move the panels from the receiving area to the case, liner, and door pre-foam areas—fork trucks, automatic guided vehicles (AGVs), belt conveyor, and overhead monorail. Both fork trucks and AGVs would require an overpack and a skid. These methods would reduce truck loads and create dunnage removal problems. They would also add to product cost.

Belt conveyor would offer the possibility of feeding individual panels to specific stations on each line by the use of bar coding. Panels could be automatically fed into magazines for robotic pick up, eliminating the need for manual material transfer. However, it would be difficult and costly to retrofit most existing plants with such a system.

The overhead monorail conveyor method was assumed for costing in this study [12]. This system could probably be installed in most plants even though considerable rearrangement of existing facilities may be required.

Fifteen hundred feet of enclosed track conveyor with 250 four tray hangers on six foot centers would be installed. The conveyor would run about 18 feet per minute, which would provide as many as 120 panels per minute to any one station. The case line would require only 18 panels per minute.

This system, with required drives and other auxiliary equipment, was estimated by Unibuilt, a division of Jervis B. Webb Company (Appendix L) to cost approximately \$110 per foot, installed [12].

It was assumed that 2000 square feet of floor space would have to be added, either as a mezzanine or a building appendage, to offset the space consumed by rearrangement to install this system. Actual rearrangement requirements and costs would have to be adjusted for a given plant and would depend on that plant's construction, layout, and available floor space.

This conveyor would deliver panels to case pre-foam, door pre-foam, and liner pre-foam, and have storage capacity for about eight hours of production.

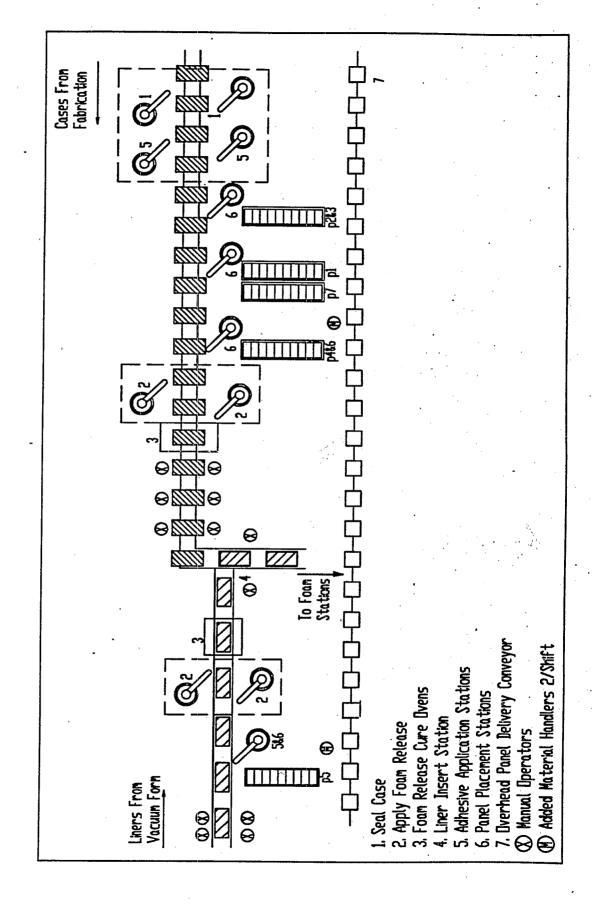
Panels will be unloaded manually from the monorail conveyor, the strap will be removed, and individual panels will be placed on the appropriate queuing conveyor at each case line, liner line, or door line station. Two material handlers per shift will service the case and liner lines, and one material handler per shift will service door pre-foam. Queuing conveyors will have appropriate indexing devices to locate each panel for accurate robot pick up.

C. Adhesive application and panel insertion

On the case pre-foam line, the case will be positioned via shot pins or some other positioning and holding mechanism and a GMF S-500, six-axis, articulated, electric robot (Appendix M) will apply an adhesive dispensed from a bulk unit to the case interior [8]. Two robots will be required to spray patterns needed to hold the six VIPs to be placed at the succeeding stations. Both robots will be supplied from a common Nordson hot melt unit (Appendix N) [5]. The hot melt material cost is included @ \$0.08 / square foot. Three more GMF S-500 robots will be used to place six panels into the case as shown in Figure 14. Each robot will place two panels.

Hot melt and panel placement stations would be added between the existing case seal stations and the foam release stations, requiring some line rearrangement. The existing foam release stations would be converted to panel adhesive application and two new foam release stations would be added after panel insertion.

Figure 14
Case and Liner Pre-Foam Areas with VIPs



On the liner pre-foam line, one GMF S-500 will apply adhesive to the fresh food back panel and place the panel on the liner back (Figure 14). A third Nordson hot melt unit would be used for this robot.

Two GMF S-500 robots will be required on the door pre-foam line. Each of these robots will apply adhesive inside the doors and place one or two panels into the doors. The robots will place one or two panels on alternate cycles to meet the station cycle time. Figure 15 shows the modified layout of the door pre-foam area. Some rearrangement also will be required on this line. A common Nordson hot melt unit would feed both of these robots.

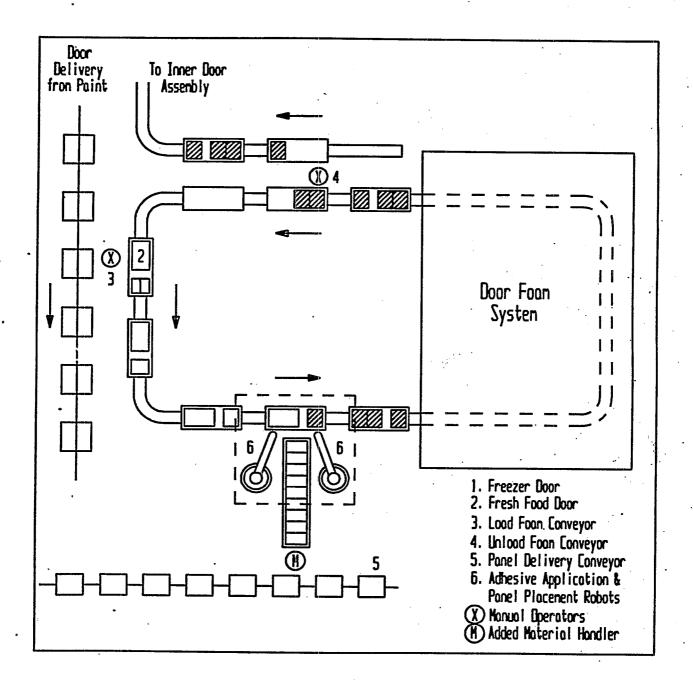
It was assumed that 4000 square feet of mezzanine or building appendage would have to be added to accommodate rearrangement required to make room for the adhesive and panel insertion stations. Actual rearrangement requirements and costs would have to be adjusted for any given plant and would depend on that plant's layout and available floor space.

A budget estimate of the cost for these stations, including eight robots, end effectors, panel and case/liner/door positioning stations and hot melt units was developed by Remtec, Inc. and is shown in Appendix O [7]. Remtec's cost estimates for the hot melt and pre-foam stations were deemed to be considerably low. Based on an estimate from Nordson, the hot melt stations were re-estimated at about 160% higher than Remtec's estimate. Also, UK engineers replaced the Remtec estimate for pre-foam stations with one about 250% higher.

D. Quality Control

Each panel will be checked for vacuum before it is placed into the case, door, or onto the liner. This will be done using a TapTone magnetic impulse unit as part of the robot end effector or as an independent unit at the end of the panel queues [14].

Figure 15 Door Pre-Foam Area with VIPs



E. Foaming around VIPs

After VIPs are positioned in the cases and doors and on the liner back, units will enter the respective foam systems where the VIPs will be foamed in place. Both the dimensions and location of the VIPs will affect the foam flow path and, therefore the quality of the fill. Panel sizes used in this study were developed with this consideration. Considerable development of VIP sizes and foam chemical compositions and distribution will be required prior to implementation of a production system. Compatibility between foam chemicals and barrier envelopes could also be an issue which may require further development.

F. Refrigerator plant equipment and incremental operating cost

Equipment required for the refrigerator plant is summarized in Table 11, along with the associated costs. A 25% contingency is included. Additional personnel and incremental operating costs are summarized in Table 12.

Table 11 Refrigerator Plant Equipment

EQUIPMENT	NUMBER	VENDOR	COST/FACH	TOTAL	CHIDDING	WIDDING INSTALL TARGET	TOTO 1
			-		Okur muzo	MOLINGTHICKI	IOIALCOSI
Receiving docks	7		\$20,000	\$40.000			000
Receiving area	45 CO 1/2/10			00000			940,000
A distance			340/sq. II.	390,960			390,960
Adjustoveyors		STEWART GLAPAT	45,000	45,000	\$1,350	\$4.500	50.850
Flow thru racks	11	MATHEWS	29,000	319,000	5.000		355 900
Sortation conveyor		MATHEWS	65,000	65,000	3,000		74 500
Bar code readers	9		3,000	18,000	500		20.300
Overhead conveyor	1500 ft.	UNIBUILT	\$110/ft.	165,000	INCLINED.		165,000
Conveyor drives	6	UNIBUILT	6.000	18,000	INC LIDED	CHOCK LINE	10,000
Hangers	250	UNIBUILT	1001	25,000	1 000		10,000
Robots	00	GMF.	100 000	000,000	1,000	,	27,000
Dobot tooling and)	TATO ALL	700,000	000,000	12,000	80,000	892,000
room tooming-case		KEMIEC	,	28,000		2,800	30.800
Robot tooling-door		REMITEC		12,000	•	1.200	13 200
Robot tooling-liner		REMITEC		8.000		00%	003.0
Hot melt stations	ო	NORDSON	41.000	123,000	3,690	12 300	120,000
Vacuum check	\$	BENTHOS	26,000	120,000	1,000	2,000	130,790
Asm. line stations			000	000,001	000:1	15,000	144,300
Case line	2	REMITEC	20.000	100,000	3 000	10 000	113
Door line	2	REMITEC	20,000	40.000	200	000,4	113,000
Tine Tine	*		00000	200	1,200	4,000	42,200
	-	KEMIEC	20,000	20,000	\$600	\$2,000	22,600
Kearrangement	6,000 sq. ft.	-	\$50/sq. ft.	300,000			300,000
Spare parts				\$95,000			205 000
•							00000

Total cost 25% Contingency Total with contingency

\$2,946,400 736,600 \$3,683,000

Table 12
Additional Operating Cost — Refrigerator Plant

	NUMBER	NUMBER HOURLY RATE	ANNUAL WAGE*	BENEFITS	OVERHEAD	OVERHEAD ANNUAL COST
				(40%)	(200%)	
SALARIED PERSONNEL			·	-	·	
Foreman	2		\$30,000	\$12,000	-	\$84,000
HOTIDI V DEDCONNET						i pingga
Receiving	9	\$12	21,120		42,240	380,
Maintenance	2	\$21	36,960		73,920	221,760
Material Handlers	9	\$15	\$26,400		\$52,800	475,200
				-	٠	\$1,077,120
Total additional						
annual operating cost		·			,	\$1,161,120

*Based on 220 days/year for hourly personnel.

TOTAL PROGRAM AND PRODUCT COST FOR VACUUM INSULATION PANEL PRODUCTION AND INSTALLATION

Program Cost

Program costs are non-recurring costs to plan and implement the project. These costs include investment to purchase and install facilities and equipment, expense for tooling, and any rearrangement expense required in the existing refrigerator plant. Historic ratios of investment and expense for similar projects were used.

Program costs also include manpower to plan and implement the project, and start-up cost incurred in both the panel plant and the refrigerator plant. Seventy-five thousand dollars per man year was used for manpower cost.

Start-up costs for the panel plant includes manpower, as described in the section on "Project Schedule and Start-up," associated overhead and material for 50,000 development panels, and lost labor and material from the start-up curve. An assumption was made that 60% of the silica can be reclaimed from panels produced during development. An estimate of start-up cost at the refrigerator plant also is included.

A summary of the program cost is shown in Table 13.

Product Costs

Product cost includes all direct material and direct labor included in or added to the product or its packaging and shipping and associated overhead cost. Overhead includes items such as overtime premium, night shift bonus, rework, scrap, and hourly employee benefits (medical insurance, vacation and holiday pay, etc.).

Other operating costs include utilities, trash removal, taxes, insurance, office expenses, security, safety, etc. No added warranty costs are included although there is likely to be additional warranty cost as a result of the incorporation of VIPs. Some amount of warranty reserves should be planned for service calls which may result from VIPs.

Table 13
Vacuum Insulated Panel Manufacturing
Program Cost (\$ million)

ITEM	INVESTMENT	EXPENSE	MANPOWER	START-UP	TOTAL
Panel Plant	\$11.6	\$3.4	6'0\$	\$1.1	\$17.0
Refrigerator Plant	\$2.3	\$1.4	\$1.1	\$1.8	\$6.6
Totals	\$13.9	\$4.8	\$2.0	\$2.9	\$23.6

Table 14 summarizes the added product cost to add 29 board feet of VIPs to 21 or 24 cubic foot refrigerators being produced at a volume of 300,000 per year.

Some appliance manufacturers may have designs with condenser loops to heat the mullion or cross braces in the doors. These parts may need to be retooled to remove interference with VIPs. Cost to retool these parts and the added product cost, if they require additional material, is not included in these summaries.

Sensitivity Analysis

To test the sensitivity of costs per board foot of VIPs, a sensitivity analysis was made by varying certain elements of product cost and program cost and recalculating the resultant cost per board foot. In order to include program cost in this analysis, these cost were amortized over a five year period or 43.5 million board feet of VIPs (300,000 refrigerators/year x 29 board feet of VIPs/refrigerator x five years). This analysis is shown in Table 15.

Project Schedule and Start-Up

After feasibility is established and funds are appropriated, it would take about two and one half years to be in production as depicted in Figure 16. Since product redesign is limited to the addition of VIPs to existing refrigerators, the longest tasks are equipment procurement, installation, and development. Some minor modifications to existing refrigerator parts tooling may be necessary and considerable product evaluation would be required.

The panel plant would be staffed with partial crews six months prior to start-up. These would include the plant manager, quality control manager, material control manager, financial manager, one foreman, one skilled maintenance person, one control person, and one material handler. The full plant crew would be added two months prior to production.

It is estimated that after a four to five month development period about seven weeks would be required to bring the plant up to rate as depicted in Figure 17. Current users of

Variable Manufacturing Transportation & Installation Cost for VIPs for One 21 Cubic Foot Refrigerator (29 Board Feet of VIPs) Table 14

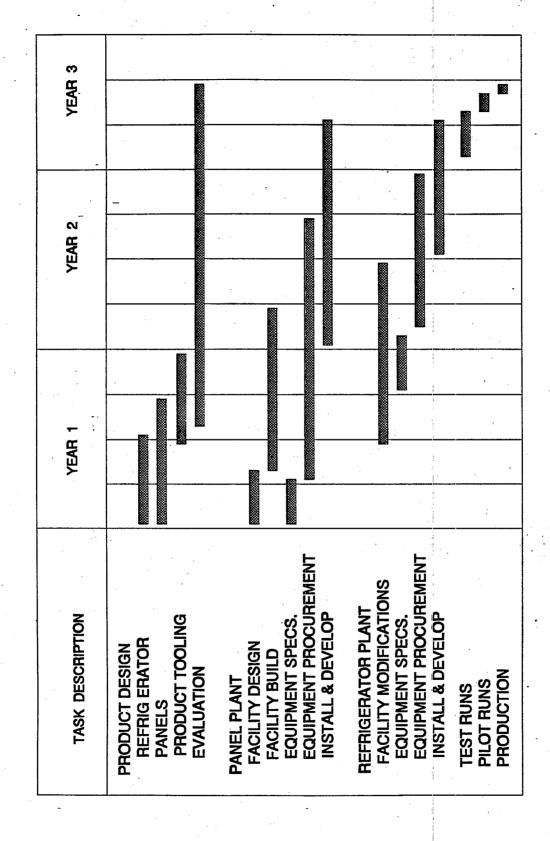
ТЕМ	DIRECT MATERIAL	DIRECT LABOR & OVERHEAD	OTHER OPERATING COST	TOTALS
Silica (29 LBS)	\$21.75			\$21.75
Porous Bag (80 FT2)	\$2.88			\$2.88
Barrier (83 FT2)	\$9.21			\$9.21
Adhesive	\$2.27			\$2.27
Panel packaging	\$0.16		• •	\$0.16
Displaced foam	\$5.81			(\$5.81)
Panel manufacturing		\$4.49	\$0.89	\$5.38
Panel transportation	· · · · · · · · · · · · · · · · · · ·		\$0.66	99.08
Panel installation		\$3.87		\$3.87
Totals	\$30.46	\$8.36	\$1.55	\$40.37
				(\$1.39/board foot)

Table 15 VIP Cost Sensitivity Analysis

	VARIABLE MFG. COST/		TOTAL COST/
	BOARD FOOT	BOARD FOOT	BOARD FOOT
•		,	
e de de la company de la compa	\$1.39	\$0.54	\$1.93
VARIABLES	·		
MATERIALS:			, '
Silica			
+10%	01.47	•	
-10% -10%	\$1.47		\$2.01
	\$1.32		\$1.86
-20% ·	\$1.24	•	\$1.78
Foam			·
+10%	\$1.37		\$1.91
+20%	\$1.35		\$1.8 9
+30%	\$1.33		\$1.87
PANEL PLANT OPERATING COSTS			
+25%	\$1.44	ق	#1.00
-25%	\$1.34		\$1.98
-22 10	\$1.54		\$1.8 8
PROGRAM COSTS:			
Buy existing building	1		%.
at \$25/squre foot		\$0.48	\$1.87
•	1	40.10	Ψ1.07
Building at 0\$ cost from			
industrial development			
organization		\$0.45	\$1.8 4
·		Ф U.43	\$1.8 4
Manpower			
+25%		ተለ መ	
-25%		\$0.55	\$1.94
- 200 10 •		\$0.53	\$1.92
[°] Panel plant			
Start-up costs		•	,
, +25%		\$0.56	\$1.95
-25%		\$0.52	\$1.93 \$1.91

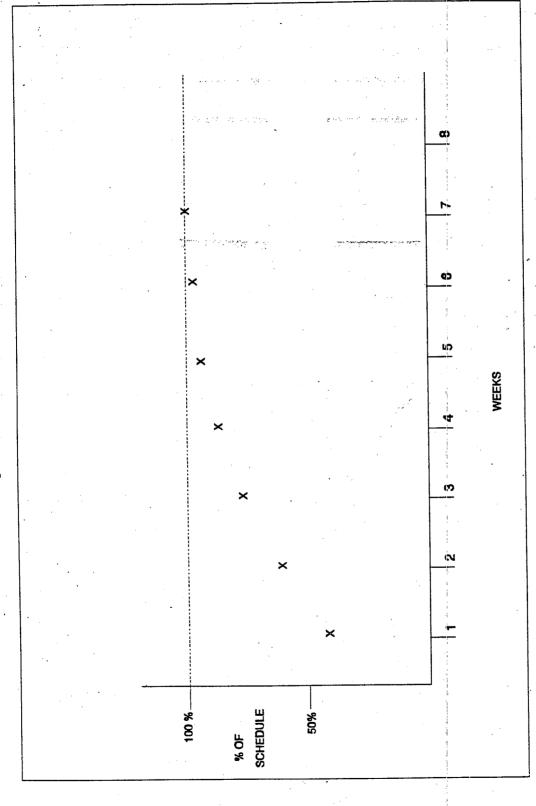
^{*\$23.6/}MM amortized over 5 years or 43.5MM board feet

Figure 16 VIP Project Schedule



form, fill, and seal equipment felt this was a conservative estimate, considering the development period planned [18].

Figure 17 Startup Curve - VIP Plant



THICK WALL ALTERNATIVE

Another approach to increasing the thermal resistance of the refrigerator cabinet is to increase thickness by adding additional non-CFC foam insulation. This section estimates the manufacturing cost impact of increasing insulation. Since this scenario is more likely on smaller refrigerators (<21') an 18' refrigerator, which represents a major share of the market, was used for this analysis.

Facility Assumptions

A facility producing five hundred thousand 18 cubic foot refrigerators per year was assumed. Multiple models in multiple sizes would further complicate this analysis and would definitely affect the cost estimates.

Scenarios

Four increases in insulation thickness from the current representative product were studied. These were +0.5", +1.0", +1.5", or +2.0". Thickness was increased on top, bottom, back, doors, and both sides.

Four methods were used for increasing the external dimensions to accommodate the thicker insulation.

- Case "All" allowed all external dimensions of the unit to increase. This case maintained the exact internal dimensions as well as the width of the front flange.
- Case "H" allowed only the height of the unit to change to accommodate the change in thickness, and reconfigured the inside to maintain 18 cubic feet of storage space. For example, when 1" of insulation is added to the top, bottom, back, doors, and both sides, the new height must become 74.5" since the width is held at 29.5" and the depth at 31.5" (Table 16). The liner would be long and narrow.

- Case "W" allowed only the width of the unit to change and maintained the internal volume.
- Case "D" allowed only the depth of the unit to change and maintained the internal volume.

All cases except Case "All" change the internal dimensions of the refrigerator. Typically, a given size box is used for numerous models which then have different internal parts or features to upgrade the model. For this reason, retooling cost for these scenarios could be \$5 - \$10 million more than case "All".

This analysis was made with the understanding that there are restrictions to dimensional changes:

- Any increase in depth beyond the current 27.75" (w/o door) prohibits entry through 28" doors and, reduces the market served; shallowness is an important consumer feature and any increase in depth makes the box less marketable. From a manufacturer's viewpoint, a common depth across several models enhances factory productivity.
- Height is limited in FHA homes, and most others, to 84". This is caused by having an
 eight foot ceiling with a 12" soffit. Typically, a 12" cabinet under the soffit further
 reduces the limit to 72". The ability to reach into the back of a top mount freezer is an
 important consumer consideration, which puts practical limitations on height.
- Width also is limited in FHA specifications to 36". Non-FHA homes also have width limitations. Increases in width will reduce the potential market.

Thicker foam walls may present process control problems such as bowed liners, which can make shelves difficult to install at final assembly, and bowed cases, which may cause appearance problems as well as kitchen fit problems. These problems will have to be assessed and resolved during development.

Table 16
Thick Insulation Alternatives
External Dimensions (inches)
for 18' Refrigerators

	VAR	YING DIMENSIO	ON (Inches)		·
	ALL	HEIGHT	WIDTH	DEPTH	CAB. DEPTH
Current Dimensions		64.0	29.5	31.5	27.8
Added . Insulation		:			
+0.5	H-65.0 W-30.5	69.0 29.5	64.0 32.0	64.0 29.5	
	D-32.5*	31.5	31.5	33.9*	29.7*
+1.0	H-66.0 W-31.5	74.5*** 29.5	64.0 34.6	64.0 29.5	
	D-33.5*	31.5	31.5	36.3*	32.1*
+1.5	H-67.0 W-32.5	80.0*** 29.5	64.0 37.1**	64.0 29.5	
	D-34.5*	31.5	31.5	38.7*	34.5*
+2.0	H-68.0 W-33.5	85.5** 29.5	64.0 39.7**	64.0 29.5	
•	D-35.5*	31.5	31.5	41.1*	36.9*

NOTES:

- * Will not fit through 28" door with refrigerator doors removed.
- ** Exceeds FHA specification dimensions.
- *** Exceeds FHA dimensions with 12" cabinet under soffit.

Table 16 is a matrix of dimensions for each scenario. Some combination of the above cases may be the best solution when all factors are considered.

Cost Analysis:

A cost impact analysis was completed for all four levels of thickness increase, using Case "All". A retooling matrix was done for the other three cases but cost analyses were not completed. All foam insulation costs were based on CFC 11. Alternative blowing agents would very likely make these changes more expensive, at least initially.

- Variable manufacturing cost increase—An analysis of the required changes was completed for each case and the percent increase in part size was calculated. Using detailed part and material cost information obtained from an appliance manufacturer, via a nondisclosure agreement, a variable manufacturing cost increase for each part was calculated. The major contributor, by far, to the increased cost was the cost of the additional foam insulation, which accounted for well over half of the increase.
- Transportation cost increase—Carton sizes were calculated for each new dimension for all four cases (Table 17). Using standard 48' trailer dimensions and 60' high cube rail car dimensions, the number of refrigerators per load was calculated for each thickness increase in case "All" and compared to the existing load size. Using an estimated average mileage to a distribution center, an average cost per truck and rail car and an estimated percentage of truck versus rail, a transportation cost increase per refrigerator was calculated.

Cost of additional warehouse space at the factory, distribution centers and dealers was not estimated. As product/carton sizes increase more floor space will be needed. Cost of adding this space would be \$100 to \$125 per square foot. If inventory levels were reduced in lieu of adding warehouse space, service to dealers would be adversely affected, resulting in lost sales.

Table 17
Carton Sizes for 18' Refrigerators
with Thicker Insulation

		VARYING DIMI	ENSION (Inches)	
	ALL	HEIGHT	WIDTH	DEPTH
Current				
Dimensions		67.0"	32.0"	34.8"
Added				
Insulation		,	•	
+0.5	H - 68.0"	72.0"	67.0"	67.0"
	W - 33.0"	32.0"	34.5"	32.0"
	D - 35.8"	34.8"	34.8"	36.8"
		·		
+1.0	H - 69.0"	77. 5"	67.0"	67.0"
	W - 34.0"	32.0"	37.1"	32.0"
	D - 36.8"	34.8"	34.8"	39.2"
+1.5	H - 70.0"	82.0"	67.0"	67.0"
,	W - 35.0"	32.0"	39.6"	32.0"
	D - 37,8"	34.8"	34.8"	42.0"
		·		
+2.0	H - 71.0"	89.5"	67.0 "	67.0"
	W - 36.0"	32.0"	42.2"	32.0"
	D - 38.8"	34.8"	34.8"	44.4"

• Tooling and Investment cost—Required tooling and facility changes were developed for each scenario using the representative 18' refrigerator and a representative manufacturing facility. Costs were then estimated for each retool or facility change for each of the four levels of thickness change in case "All". Increases in foam demold time, caused by thicker walls, were off-set by adding foam fixtures in +1.0", +1.5", and +2.0" scenarios.

A 20% contingency was added to these numbers. This is a typical contingency factor for an estimate of this quality. A matrix of required changes is shown in Table 18. Investment costs are for capital expenditures and can be depreciated over several years. Tooling and other expenses must be written off as they are incurred. The same is true for manpower and start up cost.

- Manpower cost—Design engineering, manufacturing engineering, quality assurance, and other man years were estimated to implement each level of change in case "All".
 Seventy-five thousand dollars per man year was used to calculate manpower cost.
- Startup costs—Costs to build development models and run trial runs in the plant, plus the cost of lost units while each change is implemented, were estimated.

Product cost, including transportation, for thicker foam insulation ranges from \$12.28 for one-half inch to \$37.65 for two inches. Program costs range from \$16.6 million to \$22.5 million. Thicker foam only on the doors would cost \$3.23 and \$12.28, respectively and the program cost would be about 25% of the numbers above.

A summary of all cost impact elements is shown in Table 19. A sensitivity analysis for product cost increase/unit when the cost of foam material is increased is shown in Table 20. The cost impact of increasing insulation thickness on doors only is shown in Table 21.

Table 18
Thick Foam Alternatives
Retooling Requirements
18' Refrigerators

ALL HEIGHT WIDTH DEPTH DEPTH CABINET			VAR	VARYING DIMENSION	ASION			ΛV
CABINET case blank			ALL	HEIGHT	WIDTH	DEPTH		ALL
case blank X X X X X X X X X X X X X	•	CABINET		and the second section is not the second section in the section is not the second section in the second section is not the second section in the section is not the section in the section is not the section in the section in the section is not				
blank pierce & notch		case blank	×	×	×	×	gasket racks	×
roll former spacers X X X X X X X X X X X X X			×	×	×	×	retainer strips	×
Transmitted Transmitter			×			×	inner door asm.	×
Tront rail		u-folder, shuttle, etc.	×	×	×	×	gasket insertion	×
rear rail X X SHELVES & PANS mullion t-brackets X X Shelves mullion package X X X mullion breaker strips X X X mullion breaker strips X X X condensor loop X X X vertical bars X X X foam fixtures X X X rear access cover X X X grill X X X FOOD LINER: X X X grill X X X METAL DOOR: X X X door fab line X X X door blank X X X		front rail	×	•	×			
mullion t-brackets X X shelf tracks mullion package X X X shelves mullion breaker strips X X X veg. pans mullion breaker strips X X X veg. pans mullion breaker strips X X X veg. pan handles bottom/back X X X SYSTEM vertical bars X X X SYSTEM foam fixtures X X X X SYSTEM crar access cover X X X X Condensor grill X X X X ANDCALINER thermoform molds X X X X MISCELLANEOUS pierce & trim tools X X X X X ANDCALINER door blank X X X X X ANDCALINER thermoform molds X X X X <t< td=""><td></td><td>rear rail</td><td>×</td><td></td><td>×</td><td></td><td>SHELVES & PANS</td><td></td></t<>		rear rail	×		×		SHELVES & PANS	
mullion package X X shelves mullion X X X veg. pans mullion breaker strips X X X veg. pans mullion breaker strips X X X veg. pan sort. bottom/back X X X SYSTEM vertical bars X X X SYSTEM foam fixtures X X X SYSTEM FOOD LINER: X X X X MISCELLANEOUS pierce & trim tools X X X X X MISCELLANEOUS door fab line X X X X X X X X X X X X X X X X X X		mullion t-brackets	×		×		shelf tracks	
mullion X X veg. pans mullion breaker strips X X X veg. pans condensor loop X X X veg. pan handles bottom/back X X X SYSTEM vertical bars X X X SYSTEM foam fixtures X X X Condensor rear access cover X X X X Condensor grill X X X X And present grill X X X X And present grill X X X X And present grill X X X X And present And present goor blank X X X X X X And present		mullion package			×	×	shelves	
mullion breaker strips X X X veg. pan cvr. condensor loop X X X X X Veg. pan handles Y Veg. pan handles Y Veg. pan handles Y		mullion	×		×		veg. pans	
condensor loop X X X X X X X X X X X X X			×		×		veg. pan cvr.	
bottom/back X X X SYSTEM vertical bars X X X Evaporator foam fixtures X X X Condensor grill X X X Condensor grill X X X Condensor FODD LINER: unit mount unit mount Incendensor FODD LINER: MISCELLANEOUS fresh food top fresh food top pierce & trim tools X X X X X METAL DOOR: X X X X A PACKAGING door blank X X X X X X A door blank X X X X X A PACKAGING door blank X X X X X X A A PACKAGING door blank X X X X X X A A A<		condensor loop	× —	×	×		veg. pan handles	
vertical bars X X X Condensor foam fixtures X X X condensor rear access cover X X X condensor grill X X X condensor rear access cover X X condensor grill X X X MISCELLANEOUS pierce & trim tools X X X X Kresh food top door fab line X X X X X Acceptom door blank X X X X X X Acceptom door blank X X X X X Acceptom door blank X X X X X Acceptom door braces X X X X Acceptom door braces X X X X Acceptom DOOR LINER: X X X <t< td=""><td>-</td><td>bottom/back</td><td>×</td><td>×</td><td>×</td><td></td><td></td><td></td></t<>	-	bottom/back	×	×	×			
foam fixtures X X X coadensor rear access cover X X Condensor grill X X X cvap cvr. Hormoform molds X X X X MISCELLANEOUS pierce & trim tools X X X X X Irresh food top Irr. bottom door fab line X X X X X X PACKAGING door blank X X X X X X X PACKAGING door blank X X X X X X X PACKAGING door braces X	68	vertical bars	×	×			SYSTEM	:
Condensor	-	foam fixtures	×	×	×	×	evaporator	
Miscellane X	•	access	×		×		condensor	
molds X X X MISCELLANEOUS I tools X X X Kresh food top I tools X X X Kresh food top I tools X X X X X X X X X X X X X X I molds X X X X I mader X X X X I mader X X X X		grill	×		×		evap cvr.	
molds X X X Kresh food top fresh fresh fresh food top fresh fr							unit mount	
molds X X X X Kresh food top fresh fresh food top fresh fresh food top fresh fres		FOOD LINER:						······································
tools			×	×	×	×	MISCELLANEOUS	
Trz. bottom Coor handles Coor		pierce & trim tools	×	×	×	×	fresh food top	
X							frz. bottom	
X		METAL DOOR:			•		door handles	×
Name		door fab line	×	×	×	•		
X X X Carton molds X		door blank	× —	×	×		PACKAGING	
molds X <td></td> <td>door braces</td> <td>×</td> <td>×</td> <td>×</td> <td></td> <td>carton</td> <td>×</td>		door braces	×	×	×		carton	×
LINER: skid skid oform molds X X X & trim X X X Inander fixtures X X X Inander cure tunnel X X X X					٠		top & bottom caps	×
oform molds X X X Pad s. & trim X X X Inander fixtures X X X X cure tunnel X X X X		DOOR LINER:			1		skid	× _
& trim X X X Inal asm. fixtures X X X X cure tunnel X X X X		thermoform molds	×	×	×		pad	×
fixtures X X X X final asm.		pierce & trim	×	×	×		bander	× —
cure tunnel X X		foam fixtures	×	×	×	×	final asm.	×
		cure	×	×	s'	×		

				·	·.
DEPTH		×××	** *	××	×××××
SION WIDTH	· ××××	 ××××	×××	××	×××××
VARYING DIMENSION LL	××××	×	·	×	× ××
VARY ALL	× × × ×			×	****
	gasket racks retainer strips inner door asm. gasket insertion	SHELVES & PANS shelf tracks shelves veg. pans veg. pan cvr. veg. pan handles	SYSTEM evaporator condensor evap cvr. unit mount	MISCELLANEOUS fresh food top frz. bottom door handles	PACKAGING carton top & bottom caps skid pad bander final asm.

Cost to Increase Insulation Thickness on 18' Refrigerators Internal Dimensions Maintained/External Dimensions Varied (1991 Jollars) Table 19

START-UP (\$millions)	1.2	1.2	1.5 	1.5
MANPOWER (\$millions)	4.6	5.1	5.6	6.2
EXPENSE (\$millions)	7.2	7.5	7.8	8.0
INVESTMENT (\$millions)	3.6	4.3	5.4	8.9
TRANSPORTATION INCREASE/UNIT	\$5.47	7.36	7.36	\$8.45
PRODUCT COST INCREASE/UNIT	\$6.81	13.46	21.16	\$29.20
THICKNESS INCREASE	0.5"	1.0"	1.5"	2.0"

NOTES: 1. Equipment modification or replacement (if deemed necessary) to accommodate larger tools not included.

^{2.} Margin loss due to lost sales/reduced market not included.

Table 20
Thick Wall Product Cost Sensitivity Analysis

Thickness Increase	Product Cost Increase/Unit	+10% Foam Cost	+20% Foam Cost	+30% Foam Cost
0.5"	\$6.81	\$7.25	\$7.69	\$8.13
1.0"	13.46	14.35	15.24	16.13
1.5"	21.16	22.53	23. 90	25.27
2.0″	29.20	31.19	33.18	35.17

Cost to Increase Insulation Thickness on 18' Refrigerator Doors Only Internal Dimensions Maintained/External Dimensions Varied (1991 Dollars) Table 21

START-UP (\$millions)	0.3	0.3	0.4	0.4
MANPOWER (\$millions)	1.6	1.7	1.9	2.1
EXPENSE (\$millions)	2.5	2.6	2.8	2.8
INVESTMENT (\$millions)	0.3	0.4	0.5	0.6
TRANSPORTATION INCREASE/UNIT	\$1.17	4.22	4.22	\$5.79
PRODUCT COST INCREASE/UNIT	\$2.06	4.11	6.25	\$8.13
THICKNESS INCREASE	0.6"	1.0"	1.5"	2.0"

NOTES: 1. Equipment modification or replacement (if deemed necessary) to accomodate

larger tools not included.

^{2.} Margin loss due to lost sales/reduced market not included.

Implementation Timetable

Changes of this magnitude would take at least one and one-half to two years to design and implement, depending on the manufacturer's model mix and production equipment flexibility. The major time elements would be product redesign, tool and equipment redesign and procurement, and prototype evaluation.

ENERGY ANALYSIS

The total energy consumption of 18 cubic foot refrigerators with thicker foam insulation or vacuum insulation was modeled using the EPA Refrigerator Analysis program [21]. A "typical" 1991 refrigerator was used as the baseline for the analyses. Some of the dimensions and characteristics of the baseline unit, i.e. the unit without thicker walls or vacuum insulation, are shown in Table 22. Additional details can be found in the description of Model D given-in reference 22. Thicker foam calculations were made on the 18 cubic foot unit with 0.5, 1, 1.5 or 2 inches of foam added on all of the exterior surfaces, including doors.

Refrigerators which had 18, 21 or 24 cubic feet total volumes and contained vacuum panels having a resistivity of 25 h ft² °F / (Btu inch) and the dimensions shown in Table 2 were also modeled. The 21 and 24 cubic foot units were identical to the 18 with the exception of one inch added to the exterior dimensions of the 18 to make a 21 cubic foot unit and 2 inches added to the 18 to make it into a 24.

Calculated energy consumption per day decreased by as much as 24 percent for adding two inches of foam to the exterior of the 18 cubic foot unit, see Table 23. Similar energy reductions would occur for adding insulation to the exterior of the 21 and 24 cubic foot units.

Incorporating the vacuum panels into the refrigerator produced an average 16 percent energy reduction, with the 18 cubic foot unit having a slightly better improvement and the 24 slightly worse. Since panels sized for the 18 were modeled in all three units, the panels cover less of the area in the larger units and the energy reduction decreases accordingly.

Finally, comparison of the calculations for the 18 cubic foot unit indicates that addition of one inch of foam produces the same energy reduction as the inclusion of the vacuum panels. Similar results would be expected for the larger units.

Table 22 Baseline 1991 Refrigerator

Internal Volume	18.0 ft3
Recip. Compressor	5.3 EER
Refrigerant	CFC 12
INS	SULATION
r-value	7.9 h ft2 °F/(Btu in)
Freezer walls	2.375 inches
Freezer top	2.375 inches
Freezer door	1.75 inches
Fresh food walls	1.875 inches
Fresh food bottom	2.0 inches
Fresh food door	1.75 inches
·	FANS
Evaporator	8W
Condenser	10W

Table 23 Energy Consumption Analysis Results

MODEL	ENERGY CONSUMPTION				
	kWh/day	% reduction			
18 ft3 baseline	1.75				
18 ft3 +0.5" foam	1.58	9.7			
18 ft3 +1.0" foam	1.46	16.6			
18 ft3 +1.5" foam	1.38	21.1			
18 ft3 +2.0" foam	1.33	24			
18 ft3 +vac. ins.	1.46	16.6			
21 ft3 baseline	1.83				
21 ft3 +vac. ins.	1.54	15.8			
24 ft3 baseline	1.91				
24 ft3 +vac. ins.	1.62	15.2			

REFERENCES

Equipment and Material Suppliers

- Fres-Co System USA, Inc., Telford, Pa., Larry Restivo (form, fill, and seal equipment and vacuum packaging)
- 2. T. W. Kutter Inc., Avon, Ma., Fran Ventura & Vinnie Faherty, (form, fill, and seal equipment and vacuum packaging)
- 3. Mateer-Burt Co. Inc., Wayne, Pa., Diehl Mateer (auger fillers)
- 4. North America Silica, Ridgefield Park, N. J. (as of 3/1/92, the Silica Division of Degussa Corp.) Roger Caffier & Nick Ludovic. (silica material)
- 5. Nordson Corp., Florence, Ky., John McKenna (hot melt equipment)
- 6. Fluid Energy Aljet, Plumsteadville, Pa., William Rodzewich (flash driers and densifiers)
- 7. Remtec, Inc., Cincinnati, Oh., Charlie Gaynor (robots and assembly stations)
- 8. Technical Automation, Cincinnati, Oh., Tom Zito (GMF robots)
- 9. Roessler Company, Cincinnati, Oh., Ron Roessler (vacuum transfer equipment)
- 10. Advanced Material Handling/Stewart Glapat, Louisville, Ky., Les Kepley (adjustoveyors, belt conveyor)
- 11. Mathews Conveyor, Danville, Ky., Debbie Hoskins (belt and roller conveyor)
- 12. Unibuilt/Jervis B. Webb, Farmington Hills, Mi., Robert Fredricks (overhead, enclosed track conveyor)
- 13. Zellerbach, Louisville, Ky., Chuck Andres, Gary Weil (strapping and bar coding equipment and strap and cardboard cap material)
- 14. TapTone, North Falmouth, N. J., Leslie Martin (vacuum test equipment)
- 15. Oak Ridge National Labs, Oak Ridge, Tn., Tom Kollie (vacuum test equipment)

- 16. Babcock/Wllcox, Lynchburg, Va., Kenneth Camplin (vacuum test equipment)
- 17. Peabody Tec Tank, Parsons Kansas, Sharon Long (silos)
- 18. JFG Coffee Co., Knoxville, Tn., Brian Morse (user of form, fill, and seal equipment and vacuum packaging)
- 19. World Wide Equip./Kenworth, Lexington, Ky., Greg Mills (Kenworth trucks and Dorsey trailers)
- 20. Portman Material Handling/Clark, Lexington, Ky., Thomas DeLuca (Clark fork trucks)
- 21. Merriam, R. L. 1992. ERA, The EPA Refrigerator Analysis Model and Computer Program. in press, U.S. Environmental Protection Agency, Washington, D.C.
- 22. Environmental Protection Agency. 1992. Multiple Pathways to Super Efficient Refrigerators, in press, U.S. Environmental Protection Agency, Washington, D.C.
- 23. Snow Filtration, Cincinnati, Ohio, Dan Wenke (pourous bag material)

APPENDICES

A	Product information sheet – FK500LS	
В	Letter quote – FK500LS	
C	Silica silos	• • • • • • • • • • • • • • • • • • •
D	Volumetric auger filler	
E	Form, fill, and seal machine	A
F	Tap tone unit	
G .	VIP test chamber	
н	Strapping machine	. Jail
I	Adjustoveyor	
J	Bar coding unit	
K	Material safety data sheet -FK500LS	
L	Unibuilt enclosed track conveyor	
M	GMF S-500 robot	
N	Nordson hot melt equipment	
0	Remtec estimate of adhesive and nanel ins	ertion stations

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Degussa 🐠

Degussa Corporation **Product Information**

425 Metro Place North

Dublin, Ohio 43017

(614) 761-0658

PRODUCT: FK500LS

METHOD	PROPERTIES	UNIT	TYPICAL VALUE
PCM-37U	SURFACE AREA (MICROMERITICS)	sq-m/g	475
PCM-23U	MOISTURE (1) (DIN 53 198)	K	2.5
- PCM-20U	pH-VALUE (5%, DIN 53 200)		6.7
PCM-25U	TAPPED DENSITY (DIN 53 194)	3/1	80
PCM-32U-1	AVERAGE AGGLOMERATE SIZE (COULTER)	1 200	3
PCM-41U	DBP ABSORPTION (1)	g/100 g	325
PCM-03U	SILICON DIOXIDE (2)	(%	99
PCM-10U	SO4 (2)	*	1.0
PCM-51U	A1203 (2)	%	0.2
PCM-50U	Fe2O3 (2)	%	0.03

- (1) based on material dried for 2 hours @ 105 deg-C
- (2) based on material ignited for 2 hours @ 1000 deg-C

(***) currently not a standard method

CAUTION: Inhalation of synthetic amorphous precipitated silica may irritate the respiratory tract.

Adequate ventilation and, where dust occurs, a NIOSH-approved dust respirator is recommended. Material Safety Data Sheets are available on request.

This product is manufactured to comply with FDA requirements for Direct Food Additives Subpart E --Anticaking Agents (21 C.F.R. § 172,480), and Subpart D--Specific Usage Additives: Defoaming agents (21 C.F.R. § 173,340).

This product is manufactured to comply with FDA requirements for Indirect Food Additives for Use Only as Components of Adhesives (21 C.F.R. § 175,105), for Indirect Food Additives for Use Only as Components of Paper and Paperboard (21 C.F.R. § 176,200, 21 C.F.R. § 176,210), for Indirect Food Additives for Use Only as Components of Coatings (21 C.F.R. § 175,300), for use as Basic Components of Single and Repeated Use Food Contact Surfaces: Cellophane (21 C.F.R. § 177,1200), Rubber articles intended for repeated use (21 C.F.R. § 177,2600), and for Indirect Food Additives: Adjuvants and Production Aids in Animal Glue (21 C.F.R. § 178,3120).

Information herein is accurate to the best of our knowledge. Suggestions are made without warranty or guarantee of results. Before using, user should determine the suitability of the product for his inhended use and user assumes the risk and liability in connection therewith. We do not suggest violation of any existing patents or give permission to practice any patented invention without a license.

CAS#: 112926-00-8; CAS Name: Synthetic Amorphous Precipitated Silica

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North America Silica Company

a joint venture of Degussa Corporation and PQ Corporation c/o DEGUSSA CORPORATION 65 Challenger Road Ridgefield Park, NJ 07660

Phone: (201) 641-6100 Fax: (201) 807-3182

June 11, 1991

Mr. Alan Fine
U.S. ENVIRONMENTAL PROTECTION AGENCY
Technology and Substitutes Branch
Global Change Division
Office of Air and Radiation
401 M Street SW
Washington, DC 20460

Dear Alan:

Reference your work with the Center for Robotics and Manufacturing Systems at the University of Kentucky, I've enclosed two Degussa Corporation technical bulletins. These brochures "Forms Supplied and Handling of Synthetic Silicas and Silicates" and "Experience Gained in the Dust-Free Handling of Solid Materials in Powder Form with Extremely Low Bulk Densities" may help you with your University of Kentucky discussions.

Regarding the price of our two precipitated silicas that are being used for the production of vacuum insulation panels, here is some general information:

Product	Bag Weight	Bags/ Pallet	Pallet Stacking	Pallet Weight	48' Trailer Quantity	Truckload Price/Lb.
Sipernat® 22LS	25	30	3X10	750	18,750	\$.85
PK 500LS	20	15	3X5	300	15,000	\$1.12

Until your organization or one of the appliance manufacturers that you may be working with, get to a point where they require direct truckload or bulk delivery of our material, we would like to offer the following:

We agree to sell Sipernat 22LS and FK 500LS as follows:

Sipernat 22LS \$.65 per pound, any quantity, FOB our Louisville Distributor William B. Tabler & Company.

FK 500LS \$.75 per pound, any quantity, FOB our Louisville Distributor William B. Tabler & Company.

Once someone moves past the scale-up stages for this application, we can work out the details of a contract price, stocking point, lead time, bulk deliveries, etc., etc.

North America Silica Company

a joint venture of Degussa Corporation

c/o DEGUSSA CORPORATION 65 Challenger Road Ridgefield Park, NJ 07660 Phone: (201) 641-6100 Fax: (201) 807-3182

For planning purposes, these prices of \$.6500 and \$.7500 can be used as a guide for the bulk price, FOB. Chester, Pennsylvania, for these products. Hopefully, our program of subsidizing the use of these materials and making them readily available through our distributor, William B. Tabler & Company, Louisville, Kentucky, Phone No. (502) for engineering purposes. These prices can also be discussed openly with your associates.

If there are any questions on any of the above matters please give me a call.

Sincerely,

Kenneth C. Cwick
General Manager
North America Silica Company
A Joint Venture of
Degussa Corporation
and PQ Corporation

KCC:hr

Enclosures

/026

CC:

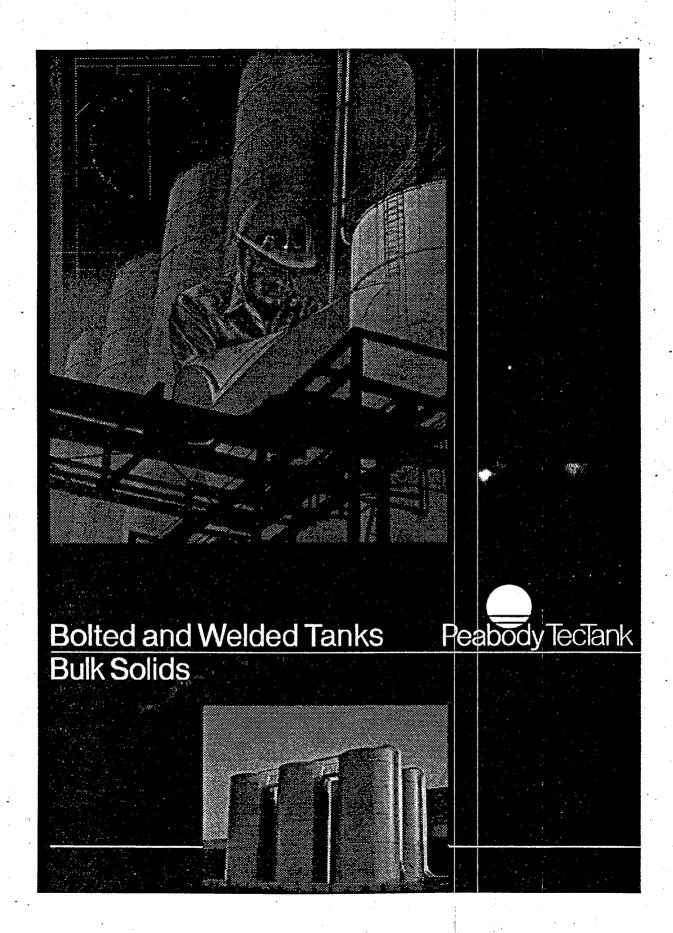
J. Boggess, William B. Tabler Co.

R. Caffier, Consultant to Degussa Corporation

J. Nastoff, Degussa Corporation R. Niccol, Degussa Corporation

R: Reich, NASILCO - PQ-VF

H. Strack, Degussa AG VTC-A





Putting More Into Storage

With Bolted and Welded Tanks for Liquids and Dry Products

At Peabody TecTank we're putting more into storage. As a result, more storage is going to Peabody TecTank. Two modern plants produce factory coated bolted and factory welded tanks for both liquid and dry storage applications. The industries we serve often require tanks that meet certain recognized standards and codes. Some of these, routinely a part of our design and fabrication, include FDA, BISSC, UBC, AISC, AWS, API, NFPA, FM, EPA, and AWWA.

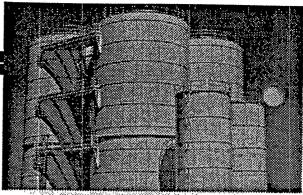
To Meet Industry's Needs

Experienced sales professionals can assist you in specifying the tank for your needs. Our engineering staff, utilizing computer aided design, provides tanks which are engineered to meet your special requirements. Peabody TecTank's customer service department can provide help during the construction phase, including supervision or complete erection service. This complete service is at your disposal, whether your tank requirements call for a large multiple tank installation or only one tank.

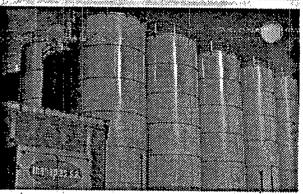
In Demanding Applications

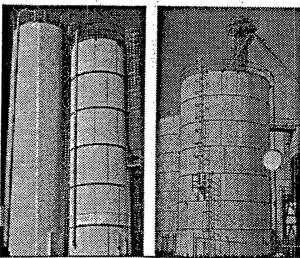
A range of sizes and factory coatings are available to tackle most industrial applications. When storing bulk solids, interior coatings are selected to protect against corrosion and abrasion. Exterior coatings are selected to provide protection against the effects of weather and the tough environment found in industrial settings. Tanks may be designed to accommodate most unloding systems; they may be hoppered or flat bottom, skirted or on structure. They may be designed for funnel flow or mass flow and may store a variety of industrial materials such as minerals, chemicals, plastics, grains, and processed foods.

Experience, service, quality...the reasons our list of repeat customers continues to grow. Our reputation is your guarantee. When you need storage, let Peabody TecTank put more into storage for you.











Foods

Our Storage tanks for food products are used extensively in the milling, baking and food processing industries. Peabody TecTank's FDA approved coatings are often specified by major food companies. Large capacity tanks are available to store up to 750,000 bushels of unprocessed grains.

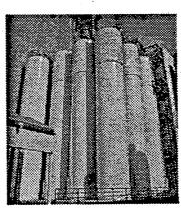
Minerals

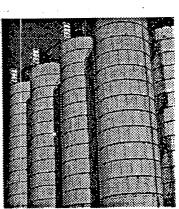
Whether it is iron powder at 250 lb/ft3, barite at 160, lime at 80 or silica gel at 6, Peabody TecTank can provide the storage. Bolted tanks are available in sizes up to 130 feet in diameter and in heights up to 129 feet. Welded tanks are available in sizes to 14 feet in diameter and 85 feet high. Peabody TecTank's bolted structures allow access for truck or railcar loadout. Spread leg welded tanks offer an economical drive trhough loadout design. Our experience and engineering give us the ability to provide special applications for storage.

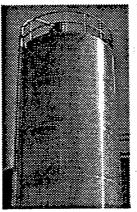
Chemicals and Plastics

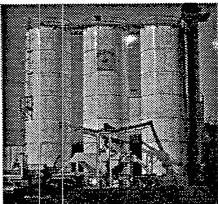
Our factory applied coatings make our bolted and welded tanks extremely popular in the chemical and plastics industries. The high cost of many of these products and the problems resulting from contamination make a superior coating system a must. Extensive use by major producers and the many processors make this one of our largest markets. Tanks are often supplied through systems companies who specialize in a complete material handling package.

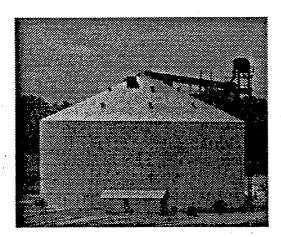
Our capability to design and fabricate a variety of hoppers and outlets allows our tanks to fit any material handling system.



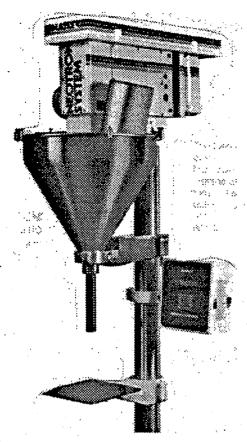








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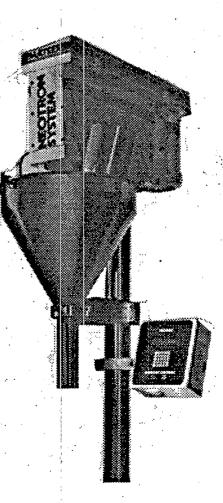
NEOTRON SYSTEM SERIES 1900

Convenient All-Electric Model

The Neotron Series 1900 filler offers the convenience of an electromechanical clutch brake without compromising the high operating standards of Neotron System fillers. The all electric Series 1900 is ideal as a replacement filling head on form, fill and seal machines, as standard equipment on automatic filling machines, or as semiautomatic filling machines. A high-cycle-life clutch is also available as an option.

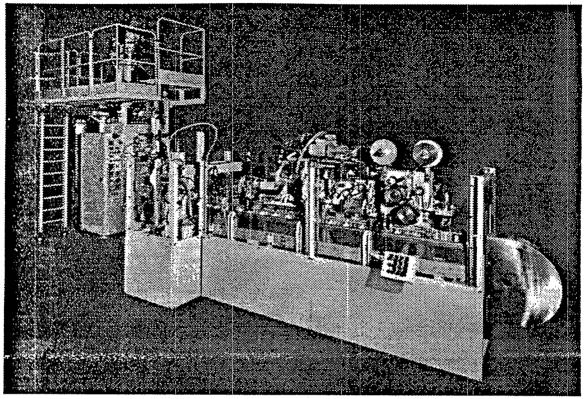
NEOTRON SYSTEM SERIES 1990 Heavy Duty Model For Difficult Fills

The Neotron Series 1990 filler is designed for use in heavy duty applications where the type of product and/or the fill size offer unusual difficulties. The rugged Series 1990 is built with a clutch brake rated at 95 foot pounds of torque and a five-horsepower drive motor.



Automatic Vacuum Packaging System

GL-26



Features

- Output Up to 40 bags per minute

 • Weight of Bags
 2 oz. to 5 lbs.
 • Programmable Logic
- Controller
- Finished Bag Types Square bottom qussetted bags with square or cathedral top
- Packaging Material Multi-ply Laminates
 •One Machine Operator
- Net Weigh Scales

Options

- Degassing Valve
- Easy Open Reclosure Tape
- •Tin Tie
- •Top and/or Bottom Flap Hot Melt
- •Double Folding of Bag Top Flap

 •Hot Stamp Imprinter
- •Gas Flush
- Vacuum Compensated With **Inert Gas**

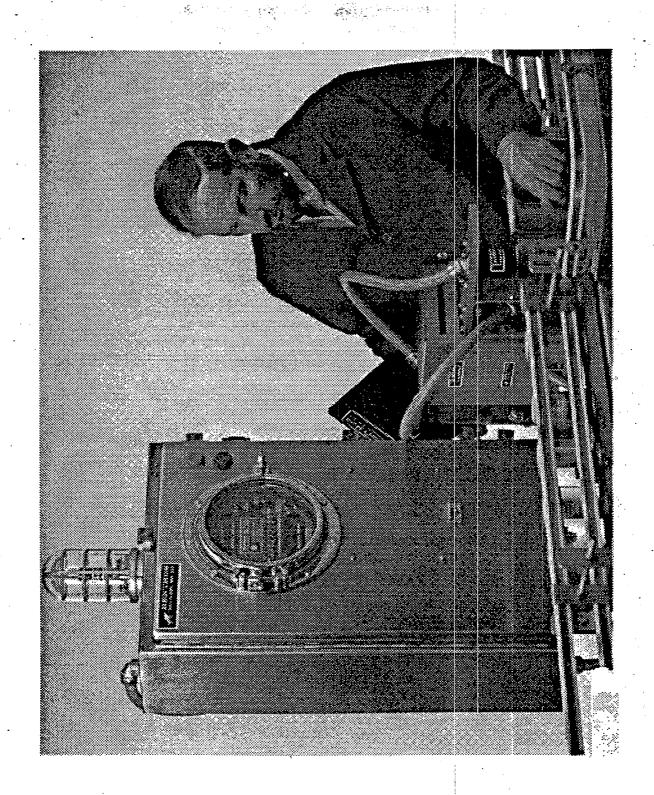
Dimensions

- •23'(L) x 13'(W) x 14'(H)
- Wieght 17,000 lbs.



fres-co®

SYSTEM USA, INC.



MODEL	DESCRIPTION	APPLICATION	SPEED PER/MIN	OPTIONS
PV2000-CM PV2000-SA	TRACKER/Conveyor Mount TRACKER/Stand Alone	Check vacuum and pressure in cans and jars without head space.	500	PV2000-DO Data Output PV2000-PS Pedestal Stand PV2000-RK Retrofit Kit
SQ-1	PLASTIC BOTTLE INSPECTOR	Checks leaks in plastic bottles with or without foil inner seal.	120	Oscilloscope Housing
4014-PF	PUFFER	Plastic cups and trays with foil membrane lids.	300	903-Spare Parts Kit
4024-1	LOW SPEED TAPTONE	Can or jar lines where headspace is available and speeds do not exceed 350 cpm.	Max speed at least 350 cpm	404-CR Crank 4024-CK Changeover 903-2 Spare Parts
4044-1	HIGH SPEED TAPTONE	Can or jar lines where headspace is available and speeds exceed 350 cpm.	1800 cpm	404-CR Crank 4044-CK Changeover 405-DL Datalogger 903-4 Spare Parts
4044-CB	AUTOMATIC LINE TAPTONE FOR VACUUM TESTING FOIL PACKAGES	Vacuum bagged products from such systems as SIG VAC, where a "brick" results.	Contact Factory	404-CR Crank 405-DL Datalogger 903-7 Spare Parts
4054-2-CB	AUTOMATIC CASE TAPTONE FOR VACUUM TESTING FOIL PACKAGES	Same as 4044-CB, for testing products in the sealed case. Inspection grade conveyor included.	50 cases	405-SM Spray Marker 405-DL Datalogger 405-R Rejector 903-8 Spare Parts
4054-4	AUTOMATIC CASE TAPTONE	Warehouse or distribution center testing of product with headspace in the sealed case. Inspection grade conveyor included.	50 cases	903-5 Spare Parts 405-SM Spray Marker 405-DL Datalogger 405-R Rejector 405-SCD Swell Can Det 4054-CK Changeover
4104-4	AUTOMATIC SWELLED CAN DETECTOR	Warehouse or distribution center testing of product with or without headspace in the sealed case. Inspection grade conveyor included.	50 cases	405-SM Spray Marker 405-R Rejector 903-6 Spare Parts
4049-4A	CASE SCANNER	Subjective/manual testing of cans/jars with clear headspace in the case or individually.	N/A	4049-4H Çase Head 4049-S Single Head
4049-A	PORTABLE TAPTONE	Subjective/manual testing of cans/jars with clear headspace.	N/A	N/A

VACUUM PACK INSPECTION SYSTEM:

The vacuum pack inspection system(s) were designed and built by Babcock & Wilcox, CIM Systems, to inspect vacuum packed insulation panels used in the appliance industry. The system reports the actual vacuum in the pack on a monitor for operator disposition. The system utilizes a custom designed vacuum chamber, a high precision pressure/vacuum transducer, and a optical laser triangulation sensor in order to measure the vacuum in the packs.

The chamber and sensor mounting design enables many different sizes of packs to be inspected by the system. The control system utilizes an IBM compatible computer and B&W software to lead the operator through the inspection process. The operator initiates the inspection process from the main menu and places a pack in the chamber. Once the lid is closed, a vacuum is pulled on the chamber. The optical laser sensor, which is contained inside the vacuum chamber, is focused onto the surface of the insulation pack. When the vacuum inside the chamber reaches the same vacuum level of that inside the insulation pack, the insulation pack wrapper expands. The laser sensor detects the deflection (expansion) of the insulation pack and triggers the computer to read the vacuum transducer at the time of deflection. This reading is an indication of the actual vacuum level inside the insulation pack.

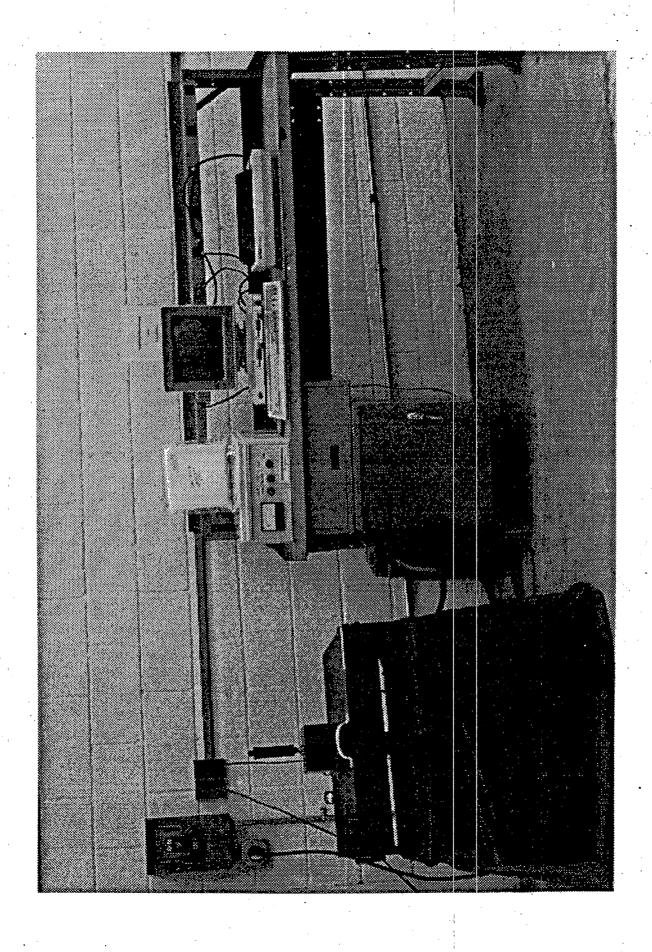
ADDED FOR AUTOMATED HANDLING:

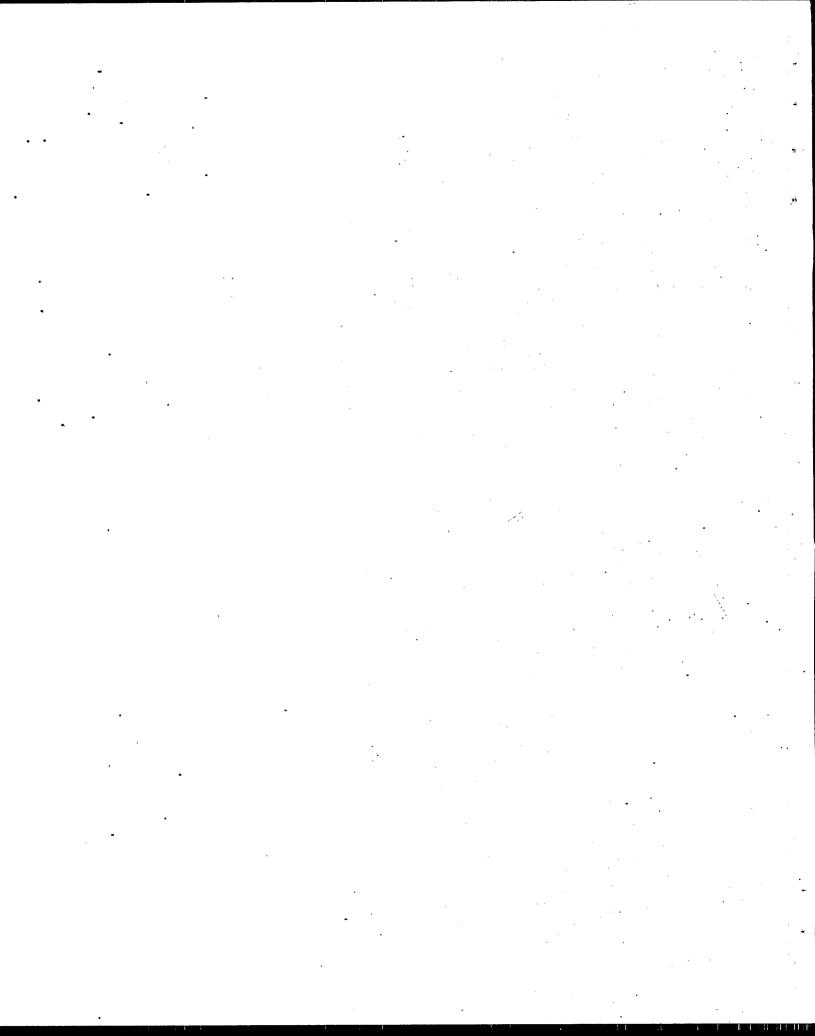
The current design is a manual system with respect to the handling (loading and unloading) of the insulation panels, and initiation of the functions via the terminal. The vacuum chamber design utilizes gas springs to assist the operator in opening and closing the heavy cover, similar to the liftback of an automobile. This design can easily be modified to accommodate robotic handling where the robot would load the panels into the chamber, utilizing for example, vacuum suction pads for the end effector, and communicate with the vacuum system computer to start and stop the processes without operator intervention. The vacuum system software, with some modification, can then perform the inspection cycle automatically where the only additional hardware required to facilitate fully automatic operation would be to replace the gas springs with solenoid controlled air cylinders.

System throughput is directly dependent on the chamber size and the percentage of volume that is occupied by the pack being inspected (as well as the vacuum pump size). For "higher" vacuum packs (below 3 torr), the longest step of the inspection cycle is the time required to pull the vacuum on

the vacant portion of the chamber. Therefore, this time can be greatly reduced (approaching the 10 second range) if the chamber(s) can be sized to be only slightly larger than the packs to be inspected. Loading, closing, bleeding, opening, and unloading (the remaining steps of the cycle) only require a cumulative of about 10 additional seconds). In order to support higher throughput requirements, several vacuum pack inspection systems can be utilized per robot.

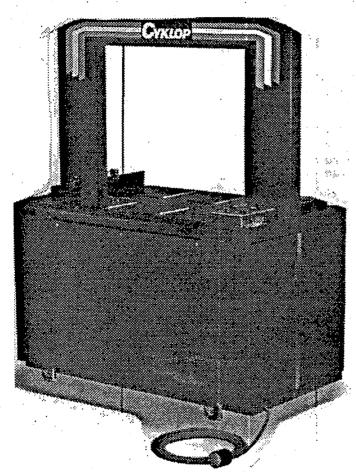
Babcock & Wilcox is experienced with custom automated robotic handling and inspection systems, and can provide both the automated version of the vacuum pack inspection systems or the entire turnkey system. inclusive of the robot, to the end users.





CYKLOP

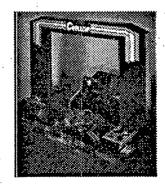
Automatic, All-Electric Plastic Strapping Machines for a Variety of Bundling, Carton Closing and Unitizing Applications



IT"S PORTABLE!
The ASM Series feature swivel casters for machine portability and a jacking leg for operational stability. Combined with its "plug in and operate" electrical requirements, the machines can be easily moved about your production area as needs change.

SIMPLE JAM CLEARING
Unlike most competitive models,
the ASM's feature a simple, very
accessible jarn clearing system.
A pushbuttom opens the strap
track allowing the operator to
remove trapped strap. Another
pushbutton cycles the sealer, cuts
off the okl strap and re-feeds.

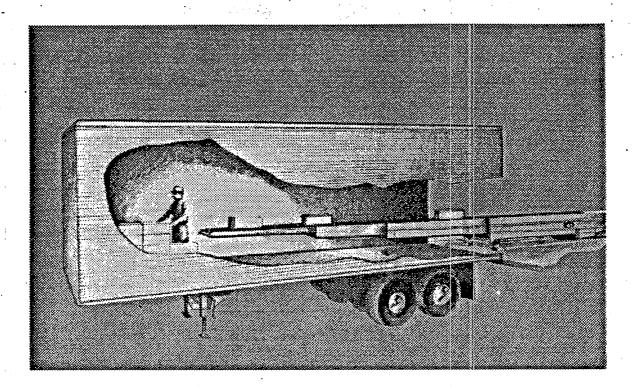
DUAL PRESS BAR OPTION
A pneumatically powered dual
press bar option for some track
sizes is available with up to 120
lbs. of compression to help presettle package contents, close
telescoping cartons and stabilize
packages during the strapping
operation.



POWERED CONVEYOR AVAILABLE

The ASM-1A features powered belt conveyor with hinged top plates and photo-eye controls for PC controlled application of one or two straps. The ASM-1AA with adjustable table top and external dispenser is available with either roller top or belt conveyor.

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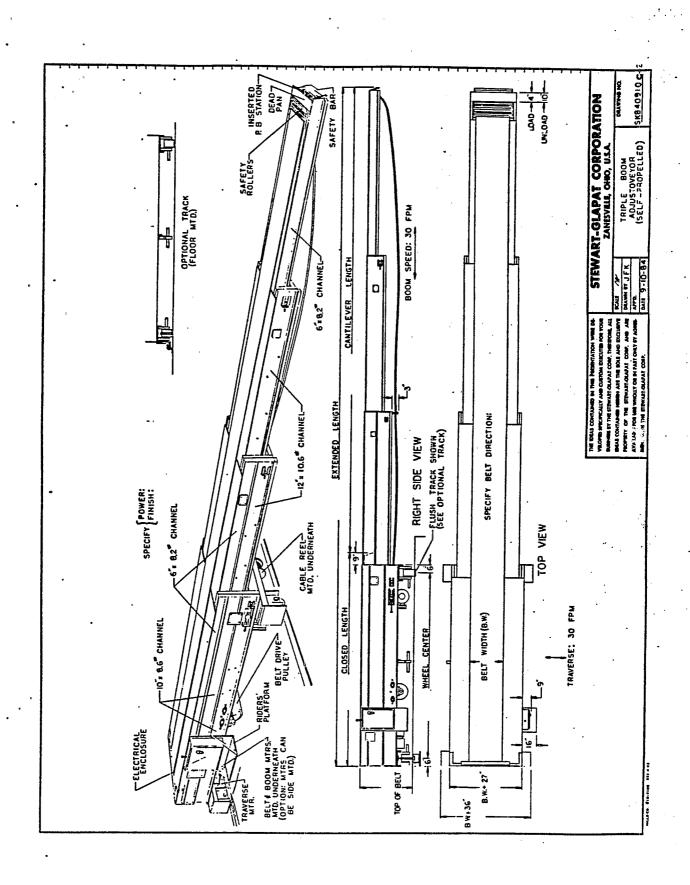


Adjustoveyor extendable conveyors offer many MONEY-SAVING benefits

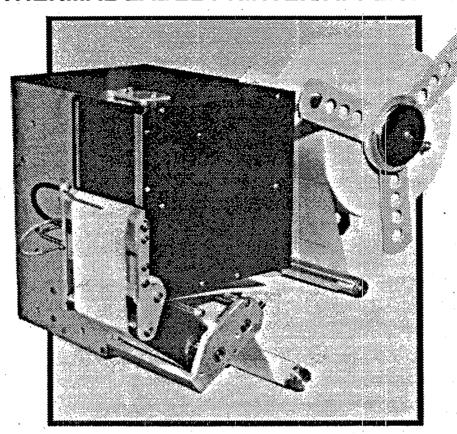
When you use the job-proven Adjustoveyor you can expect these benefits to your dock and wharehouse operations:

- Labor productiviy improvement of 500% in most applications
- Reduced turnaround time for trucks, improving their on-the-road productivity
- Reduced product damage, resulting in fewer claims and improved product quality
- Improved dock space utilization through the avoidance of staging areas
- Smooth uninterupted flow to or from the truck

These operating benefits translate directly to cost reductions which easily allow the Adjustoveyor to leap over those 40% after-tax corporate hurdle rates used for capital bugeting decisions. In fact, many applications result in a payback of less than one year! If the productivity improvement of your overall system is one of your objectives, the Adjustoveyor is your best investment.

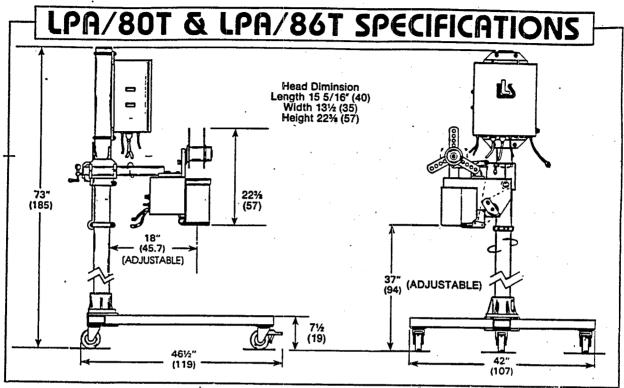


LPA/80T LPA/86T THERMAL LABEL PRINTER/APPLICATOR



The LPA/80T and LPA/86T are heavy duty industrial direct thermal printer/applicators which create high quality barcodes and variable text on demand. The LPA/80T can process up to a 4" wide label and the LPA/86T up to 6" in width. Labels are smudge proof and oil and water resistant. Print rate is up to 4" per second. The thermal printing process uses no ink or ribbon. Images are produced on temperature sensitive label material as it moves past a stationary print head. Dual microprocessors control printing and labling functions. Advanced programming includes graphic data base systems, free format systems and custom software packages. Each printer/applicator includes stand, control box and product detection devices. Already proven by years of service, the LPA/80T printer/applicators provide a standard in high speed in line thermal label applications.





Applicator:

• Drive Motor: 1/14 HP gear motor, 115 VAC

• Label Control: Photoelectric sensing, electric brake

Application Method: Air cylinder actuated tamp pad or high pressure air blast Construction: Anodized aluminum and stainless steel

LPA/80T 4 1/4" wide x 4" repeat (111mm x 102mm) max-lmum standard size. Larger sizes available at extra cost. LPA/86T 61/2" wide x 4" repeat (165mm x 102mm) max-Imum standard size. Larger sizes available at extra cost.

Method: Ceramic thick film thermal print modules.
Method: Ceramic thick film thermal print modules.
Print Pattern: LPA/80T single row of 300 print points, approximately 76 dots per inch. Dot dimension 0.013" (0.33mm). Print field width 3.9" (99mm).
LPA/86T single row of 450 print points, approximately 76 dots per inch. Dot dimension 0.013" (0.33mm). Print field width 5.9" (150mm).
Rate: 3" (76mm) per second standard. Rate may vary depending on application.

Electronics:

Enclosure: NEMA 12, water resistant; may be remote

Control: Z80 Microprocessor CPU with solid state memory and control chips. Label format, character generator, fixed label data and print routine are stored · in plug-in EPROM's.

 Display: 16 Character LED display indicates the status of the printer/applicator. Test functions are commanded from a 16 button keypad and read out on the display. In addition, error messages are displayed to pinpoint mechanical malfunctions or input data faults to minimize troubleshooting time.

The unit may operate as a stand-alone printer/applicator by means of the integral keypad or an optional terminal using on-board programming. Data input can come from any computer output device with an RS232 serial inter-face, such as an electronic scale, barcode reader or host computer.

Label Material:

Thermal sensitive paper: smudge proof, oil and water resistant. Paper is available for infrared scannable barcodes (900 nanometers).

Label Formatting:

Available barcodes are interleaved 2 of 5, Code 39, UPC and EAN. Other barcode structures can be provided. Formats are designed to suit the application. Several variable fields can be provided within a format. Character sizes can be up to 1.0".

Power Required: 115 VAC, 10 amp circuit

Air Required:

60 to 80 psi filtered (15 micron), dry air at 1/3 CFM

LORD LABEL SYSTEMS, INC. 1200 Ave. H East Arlington, TX. 76011 (214) 647-2504 1-800-433-5310



Authorized Distributor



1101 industrial Blvd Louisville. Kentucky 40219 Telephone. 502-964-6451

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Degussa Corporation

Material Safety Data Sheet

I. PRODUCT INFORMATION

Trade Name:

FK® 500LS Precipitated Silica

Chemical Name:

Synthetic amorphous silicon dioxide hydrate

CAS Registry No.:

112926-00-8

II. SUMMARY OF HAZARDS

May cause eye and skin irritation. Causes irritation to lungs and respiratory tract. If inhaled, immediately remove to fresh air. In case of eye contact, immediately flush eyes with plenty of water for at least 15 minutes, call a physician. Flush skin with water. See Section V for additional information on health hazards.

III. HAZARDOUS INGREDIENTS

A new CAS registry number has been assigned to Amorphous Precipitated Silica which will differentiate it from crystalline forms of silica. The new CAS number is as shown, 112926-00-8, changed from 7631-86-9.

Name

CAS No.

ક્ષ

T'LV®

Amorphous silica

112926-00-8

91%

10mg/m³

Not listed by OSHA, NTP, or IARC as a carcinogen.

IV. CHEMICAL AND PHYSICAL PROPERTIES

APPEARANCE:

Dry, white powder

SPECIFIC GRAVITY:

N/A

SOL. IN WATER:

Negligable

VAPOR PRESSURE:

N/A

EVAPORATION RATE:

BOILING POINT:

N/A

VAPOR DENSITY:

N/A N/A

pH:

N/A

Degussa �

Degussa Corporation .

V. HEALTH HAZARD DATA & FIRST AID PROCEDURES

Amorphous silica, unlike crystalline silica, is considered biologically benign.

EYE CONTACT:

May cause eye irritation.

SKIN CONTACT:

May cause skin irritation.

INHALATION:

Causes irritation to lungs and respiratory tract.

CHRONIC HAZARDS:

No known chronic hazards.

SIGN AND SYMPTOMS

OF EXPOSURE:

Sneezing and dryness mucous membranes (inhalation). May cause dry, chapped skin (skin exposure). May

cause redness and tearing (eye exposure).

MEDICAL CONDITIONS

AGGRAVATED BY EXPOSURE: Skin diseases (dermatitis), asthma and lung

diseases.

VI. EXPOSURE CONTROL MEASURES

GLOVES:

Tightly woven cotton, plastic, or rubber.

EYE PROTECTION:

Chemical goggles are recommended.

RESPIRATORY PROTECTION: Use NIOSH approved dust respirator where dust

occurs.

ENGINEERING CONTROL:

Use with adequate ventilation.

OTHER PROTECTIVE

EQUIPMENT:

Safety shower and eyewash fountain should be within

direct access.

PERSONAL HYGIENE:

Avoid breathing dust. Wash thoroughly after

handling.

VII. REACTIVITY DATA

STABILITY:

Stable

CONDITIONS TO AVOID:

N/A

INCOMPATIBILITY:

N/A

HAZARDOUS

DECOMPOSITION PRODUCTS:

None

150 Springside Drive Suite 110 Akron OH 44333 216-668-2235 FAX 216-668-3846

Degussa �

Degussa Corporation

VIII. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT:

Noncombustible

FLAMMABLE LIMITS:

N/A

EXTINGUISHING METHOD:

N/A

FIRE FIGHTING

INSTRUCTIONS:

N/A

UNUSUAL FIRE AND

EXPLOSION HAZARDS:

None

IX. ENVIRONMENTAL & DISPOSAL INFORMATION

ENVIRONMENTAL HAZARDS:

No known adverse effects. Not a listed

toxic chemical under SARA Title III, §302,

§304, or §313.

SPILLAGE:

Sweep, scoop, or vacuum discharged

material.

WASTE DISLOSAL METHOD:

Landfill according to local, state, and

federal regulations. Not a hazardous

waste under RCRA regulations.

X. SUBSTANCES FOR WHICH STANDARDS HAVE BEEN SET

COMPONENT:

Amorphous Silica/Percent: 91% as SiO,

OSHA Exposure Limit:

20mppcf (5mg/m3) SiO, Respirable dust. 8 hour

time weighted average.

TLV®:

10mg/m³ Total dust; 5mg/m³ respirable.

EXPOSURE ANALYSIS METHODS:

NIOSH Manual of Analytical Methods, 3rd ed.,

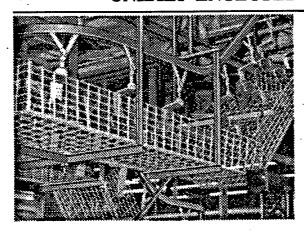
Method 7501, (1984).

XI. SOURCE OF INFORMATION

John G. Blumberg, Product Safety Coordinator, 10/19/89

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UNIBILT ENCLOSED TRACK CONVEYORS



The Unibilt Division of the Jervis B. Webb Company was created in the early 1960s to provide manufactureres of all types with a multi-purpose enclosed track conveyor. Designed and built upon the principles of increasing productivity, Unibilt®Enclosed Track Conveyors incorporate reliability, economy, flexibility and simple installation either by welding or bolting.

Unibilt Enclosed Track Conveyors contain many features normally associated with conventional I-Beam conveyors, plus features that are unique to this type of system, such as:

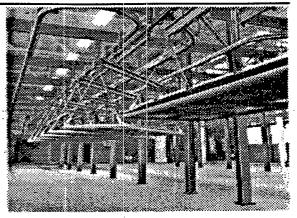
Completely enclosed chain helps prevent accidental contact with moving parts.

An enclosed track helps prevent continuation from reaching the chain or track bearing surfaces.

The universal link chain is designed to provide maximum flexibility in all directions, featuring easy assembly or disassembly with simple hand tools.

The enclosed track design helps provide protection from the elements for the chain and other moving parts.

Shorter radius curves and closer spacing of curve tangents are possible due to the universal link chain.

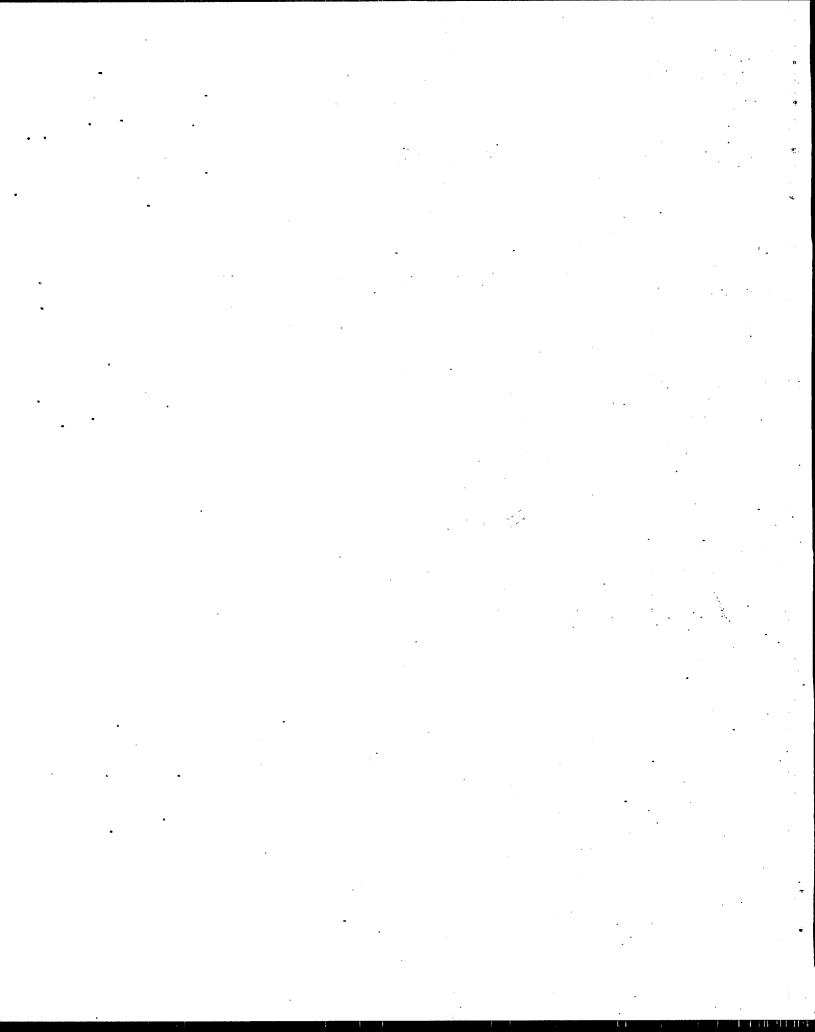


Easier installation...no bulky roller turns or traction wheels to erect.

Caterpillar-type drive units provide flexility for all enclosed track power requirements in a single compact package.

Qualified local distributors and regional Unibilt representatives are available to assist you in all phases of a conveying system: design/engineering, plan layout, installation and application.

Unibilt Enclosed Track conveyors offer a system that has applications in both simple and complex handling problems.



GMFanuc Robotics

Basic Descrition

The GMFanuc Model S-500 is a six-axis, simultaneously controlled, articulated coordinate, electro-mechanically operated robot. It is controlled by the KAREL®Robot Controller which features user-friendly programming language and built-in card slots for MAP and integrated Vision Boards. The S-500 has an exceptionally large work envelope allowing it to handle many applications.

....

Features

- . 6 axes of motion.
- 15 kg (33 lbs.) payload.
- Excellent path repeatability ±0.25mm (±0.010").
- 300° base rotation.
- 2700mm (106.3") horizontal travel.
- 4000mm (157.5") vertical travel.
- 1500mm/sec (59"/sec) max. sealing speed.
- Slender arm design.
- High speed option on axis 6 of 600°/sec.
- Analog output signal proportional to tool tip velocity.
- Precision gears and sealed-for-life bearings.
- Compact FANUC AC servo motor with absolute pulse coders.
- High efficiency, compact drive train.
- Maintenance dust covers and external lube fittings.

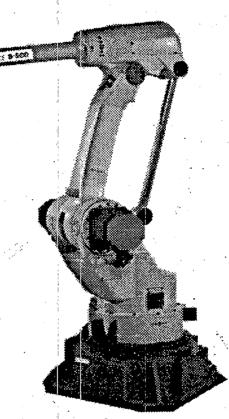
S-500 Applications

- Sealing
- Material Handling
- Deburing

- Machine Load/Unloading
- Parts Transfer
- Welding

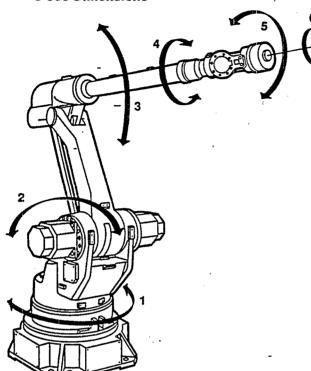
Customer Benefits

- Large work envelope for wide application range.
- Precise path control and repeatability allow consistent and predictable sealing beads.
- High speed wrist option to further minimize cycle times.
- Analog control output signal
- allows consistent bead widths throughout varying path geometries.
- Reliable and precision electronic and mechanical components mean longer MTBF and lower production downtime.
- Maintenance is quick and easy with dust covers and external lubrication on fittings.
- Safety limit switches provide overtravel protection and a safe environment for workers.



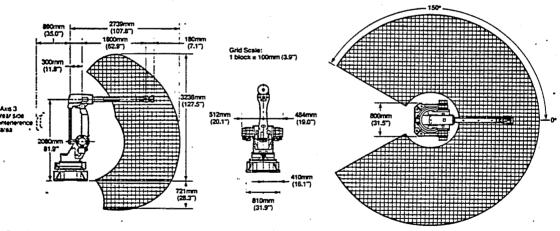
S-500

S-500 Dimensions



Capacities

Mern	1.14	Specifications ***
Controlled Ax	300 × 54	6 Dept bereit
	hod	Floor-or ceiling-mount; also well-mount, but with limited range and speed.
Motion and	Axis and	Range - Speed
Mex.Speed -	2006 1 · 4:	300***********************************
1	80de 2	160° 20759C
	2008 3 > →	160****** \$0%ec.
	8008 4 1/2	480° 1997 320% sec.
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7,447	Standard 39	900° 320″sec
7.70	accis 6 - ₹	27年 日本の日本の日本の日本の日本の日本の日本の日本の日本の日本の日本の日本の日本の日
2.00	High-speed	900" 75 2 800"/sec.
	accis 6 427	(option)
Payload :	حريان الم	15kg x 1566-15
Repeatability	型 化压缩性	+0.25mm (+0.0107)
Drive method		AC serve motor: **** ****
Position-Deter	ction	Absolute Pulse Goder
Weight-Mecha	mical Unit -	Approx. 900 kg (1,985 lbs.)



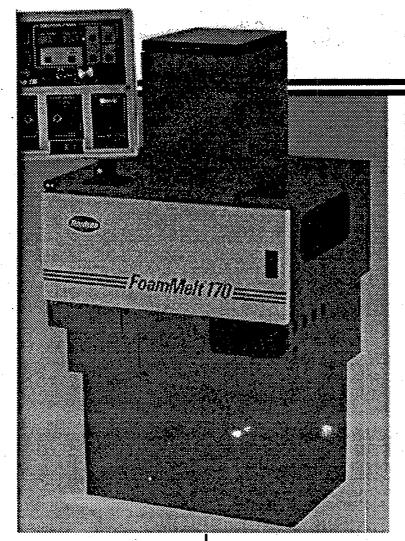
Specifications subject to change without notice



GMFanuc Robotics Corporation 2000 South Adams Road Auburn Hills. Mil 48326-2800 Literature Request 1-800-47-ROBOT Phone (313) 377-7000 Fax (313) 377-7366

GMFanuc Robotics Canada, Ltd. 6395 Kestrei Road Mississauga. Ontario Canada L57 125 Main Office (416) 670-5755 GMFanuc Robotics Europe GmbH Heinnch-Hertz-Strasse 16 P.O. Box 3345 D-4006 Erikrath 1. West Germany Main Office 211-20060

Extechications subject to change is most notice 3 89 FSP LITHO tN ∪ S 4



Automatic Density Control The Nordson 170 Series Processors feature a simple, repeatable one-step setting for maintaining consistent foamed material density. A density sensor is located in the filter/density controller, which automatically monitors and adjusts the gas/adhesive mix. It is capable of achieving density reduction to within ±2.5 percentage points of the predetermined value.

Sequential Startup

In sequential startup, the hose heaters are activated only after the processor approaches operating temperature, and the gun heaters are phased in when the hose channels are nearing their setpoints. This staged warmup process minimizes char formation, lowers energy consumption, and reduces maintenance costs by minimizing stress on seals and other sytem components.

Wide Selection Of Guns And Hoses

Fully compatible with over 100 Nordson RTD-controlled guns, Series 170 Processors can meet the requirements of almost any application. In addition to standard single-module and multi module guns, 170 units can be equipped with low-profile guns, zero-cavity guns, water-resistant guns, spray guns, and a variety of handguns. Both automatic and manual hoses are available for the 170 Processors, including standard hoses, water-resistant hoses, and the new Nordson biaxial hoses.

With the supply and return passages combined in the same bundle, biaxial hoses are very cost effective, and their superior maneuverability makes them especially useful in hadgun applications.

Additional Features

Many other beneficial features are standard on FoamMelt 170 Processors. They include:

- Quiet, variable-speed DC motor
- System Ready Delay to prevent pump operation before material in the applicator reaches operating temperature
- O-ring littings on manifold, hoses, and guns
- Filter/density controller, drain valve, and pressure control valve front mounted for easy access
- Contacts for customer-supplied inputs and outputs
- Quick electrical disconnects on hoses and guns
- Comprehensive overtemperature protection with continuous monitoring of temperatures on all zones
- · Advanced self-diagnostic capability

Nordson Foam Melt **170 Series Processors**

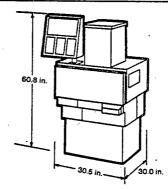
Specifications	Model 170T	Model 170H
Type of System_	Circulating, gear pump	Circulating, gear pump
Holding Capacity	35 lb	60 lb
Melt Rate ¹ -	27 lb/hr	Exceeds CDR (see next line)
Continuous Delivery Rate ²	55 lb/hr	55 lb/hr
Independent Temperature Control	Tank, manifold, 6 hoses, 4 guns	Reservoir, grid, hopper, manifold, 6 hoses, 4 guns
Temperature Control Stability	±1°F	±1°F
Temperature Control Method	PID ³	PID3
Temperature Range (All Channels)	150°F-450°F	150°F-450°F
Electrical Service	220-240 VAC, 50/60 Hz, 1/3 Ø 380Y/220 VAC, 50 Hz, 3/1 Ø	220-240 VAC, 50/60 Hz, 1/3 Ø 380Y/220 VAC, 50 Hz, 3/1 Ø
Amperage ⁴	50 A max.	50 A max.
Maximum Power Requirements	5,000 watts	11,000 watts
Viscosity Range	1,000 to 50,000 cps	/1,000 to 50,000 cps
Gas Supply	Industrial grade carbon dioxide or nitrogen (30-50 psi)	Industrial grade carbon dioxide or nitrogen (30-50 psi)
Weight	350 lb	350 lb
Hose Ports	4	4
Air Supply	90-150 psi of dry, filtered air	90-150 psi of dry, filtered air
		* ·

Note 1: Actual rates can vary depending on adhesive viscosity and other characteristics.

Note 2: Based upon a 50% density reduction.

Note 3: PID stands for proportional/integral/derivative.
Note 4: Includes applicator and total allowable hoses. guns and auxiliary devices.

Note 5: Does not include power requirement of guns and hoses.









Nordson Corporation 350 Research Court Technology Park/Atlanta Norcross, Georgia 30092 Toll Free (800) 241-8777

\$1990 Nordson Corporation 306-18-777 Issued 6/90

Unsurpassed Design, **Unmatched Performance**



Advanced Application **Technology** FoamMelt® 170 Processors employ the most advanced hot

melt application technology available - the patented Nordson® FoamMelt Process. First Introduced in 1981, the FoamMelt Process dramtically improves the performance of most hot melt adhesives by mixing them with an inert gas. Typical benefits include:

- · Increased adhesive mileage
- Longer open times
- Faster set times
- · Increased penetration
- · Improved gap-filling capabilities
- · Increased bond strength

The degree of improvement in adhesive performance will depend upon application conditions and the adhesive used. While all of the benefits of foamed adhesives will not be experienced in every application, the benefits in most applications will be significant.

The FoamMelt 170 Processors The 170 Series FoamMelt Processors are designed to provide advanced automation and pinpoint temperature control in a system that can melt and deliver up to 55 lb/hr of high-viscosity foamed material. The series includes two types of processors, a unit with a tank (the 170T), and a unit with a heated hopper and grid for high performance adhesives (the 170H).

The patented gear pump contains two stages. The first stage (the top gear set) pumps only melted adhesive. The second stage, which contains larger gears, forces inert gas into solution with the adhesive.

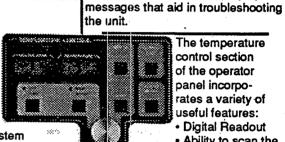
Highly Automated Control System

A sophisticated microprocessorbased controller directs the operation of FoamMelt 170 Processors. Among the functions that take place automatically after initial setup are sequential startup, temperature control, density reduction, system monitoring, self-diagnosis, and system shutdown when fault conditions are not corrected.

State-Of-The-Art Temperature Control

RTD temperature sensors and a PID (proportion/ integral/

derivative) control system combine to maintain the temperature of sistem components within ±1° F of setpoint. With 16° individual heating channels. FoamMelt 170 units can control the temperature of up to four singlemodule or multi-module guns, six hoses, the manifold, the reservoir, the grid, and the hopper. On 170T units the tank is controlled instead of the reservoir, grid, and hopper.



The temperature control section of the operator panel incorporates a variety of useful features:

- Digital Readout
- · Ability to scan the temperatures on all zones in sequence (SCAN) or on one zone

Mounted on a swivel arm at optimum

viewing height, the 170 Series control

panel is designed to cut training time,

reduce operating errors, and minimize

downtime. All controls and indicators

are clearly labled and grouped accord-

pressure, gas pressure, pump RPMs.

and temperatures on all zones. The

temperature window also displays error

ing to function. Seperate digital display

winclows provide quick access to system

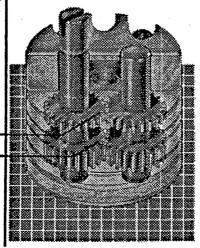
- continuously (FREEZE) Capability of displaying actual or setpoint temperatures on all zones
- Ability to display temperatures in either °F or °C
- Ability to set all temperatures to the same setpoint simultaneously (SET ALL) or enter different setpoints on each zone

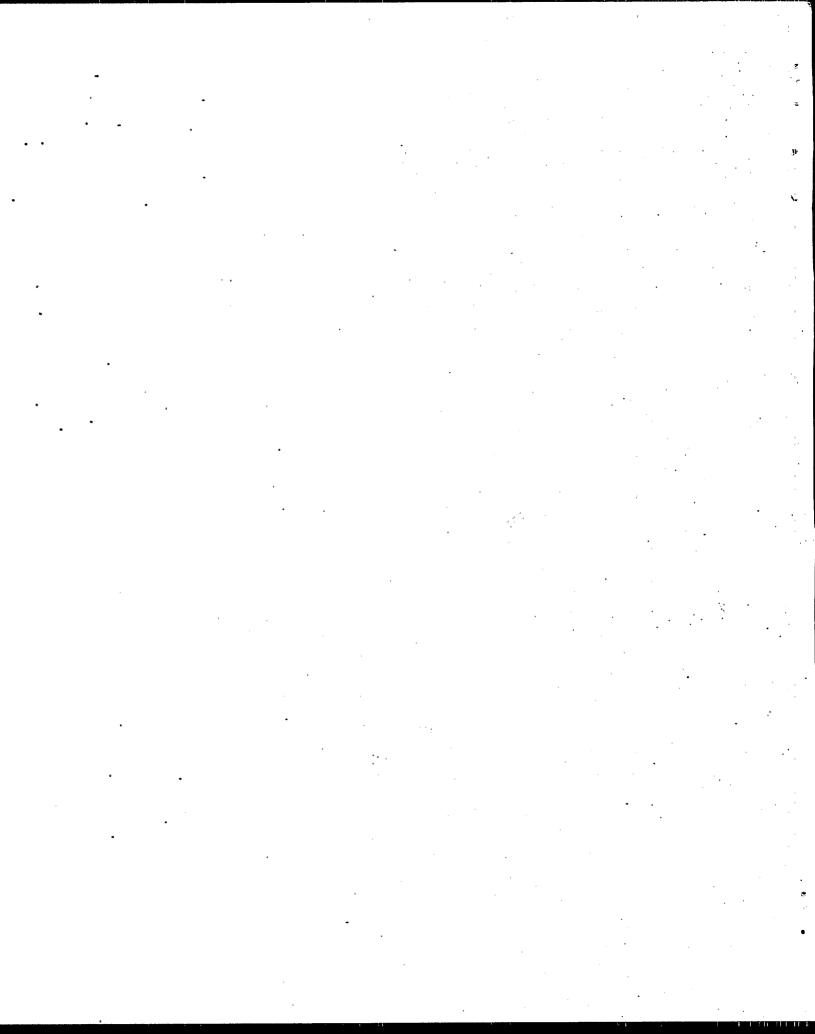


By automatically adjusting system pressure as production speed varies. Run-Up control keeps bead thickness constant. With Run-Up Control. Nordson FoamMelt 170 units produce more uniform bonds, minimize product waste, and further reduce adhesive consumption.

Large-Bore Manifold

Large-diameter flow pathways permit the use of high-viscosity materials and allow higher flow rates with reduced fluctuations in line pressure during demand cycles. Larger diameter hoses may be used with the 170 Series units to improve material flow and reduce system pressure drops.







February 20, 1992

University of Kentucky Center for Robotics and Manufacturing Systems College of Engineering Lexington, KY 40506-0108

Attention: Mr James M. Waldron P.E.

Subject: Advanced Refrigerator Manufacturing System

Dear Jim:

This letter is in response to your request for our review of a portion of your advanced manufacturing system for the production of a new low energy refrigerator.

We are responding to the portion of the project that has to do with the application of "new age" insulating panels to the inside of the case and doors, and the back side of the plastic liner. Our comments and responses will address those separate areas.

Application of hot melt spray adhesive

We feel that two (2) robots will be adequate to spray the required areas at the anticipated line rate of 200 cases per hour - 18 seconds.

The equipment required in this area is as follows:

2-GMFanuc S500 robots	_	Each		<u>Total</u>
2 Official Sour Popots	\$	100,000	\$	200,000
2-2'risers		2,000		4,000
2-adhesive dispensing systems incl dual nozzle setups		15,000		30,000
2-stop, square and meter stations in the case line conveyor		3,000		6,000
Total			. \$	240,000

Installation of liners into cases

We feel that three (3) robots will be sufficient to insert the different panel sizes into the case as it

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progresses down the line. We anticipate handling two parts at a time with the panel delivery conveyors arranged a little bit differently than your concept. Rather than having a conveyor at the 3 o'clock and the 9 o'clock position for parts 1 and 7, we would propose that those two conveyors lie along side of each other at the 3 o'clock position. The long arm of the S500 robot could reach over both conveyors to access both parts in less time than swinging over to the 9 o'clock position for each cycle.

We have not done any conceptualizing on the material handling that could be used to carry the panels from the delivery trucks or warehouse to the part delivery conveyors. We are assuming that the panels will be unbanded and placed onto the panel delivery conveyors manually. We are assuming a stack height of 2-3'.

The equipment required to install all 6 panels (four different sizes) at three work stations is:

	Each	Total
3-GMFanuc S500 robots	\$ 100,000	\$ 300,000
3-2'risers	2,000	6,000
3-dual end-effortors	6,000	18,000
3-step, square and meter stations in the case conveyor	3,000	9,000
1-central vacuum system	5,000	5,000
6-panel delivery conveyors- 8'roller	3,000	18,000
6-stop, square, and meter stations in the panel conveyors	2,000	12,000
Total:		\$ 368,000

Affixing panel to back side of plastic liner

This operation is to be done on another separate but merging line. Since only one panel is being applied, it is envisaged that a single robot fitted with a special dual purpose end-effector could do the application of the adhesive as well as present the panel to the liner.

The equipment required here is as follows:

·	<u>Each</u>	<u>Total</u>
1-GMFanuc S500 robot	\$ 100,000	\$ 100,000
1-2'riser	2,000	2,000
1-dual purpose end-effector,	6,000	4,000
spray and mat'l handling		•
1-adhesive dispensing system	15,000	15,000

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	. ¥	
1-stop, square and meter station in the liner conveyor	3,000	3,000
1-panel delivery conveyor 8' roller	3,000	3,000
1-stop, square and meter station in the panel conveyor	2,000	2,000
Total	•	131.000

4. Assembly of panels to freezer door and main door

We are assuming that the door set is moving down the assembly line in matched sets and is properly fixtured when it is stopped at the robot assembly station. Since the door panels are expected to be the same size (two for the main door and one for the freezer door) only one panel delivery conveyor will be needed. Two robots ought to be sufficient to do both the spray adhesive and material handling if special dual purpose end-effectors are used. The two robots would share the same panel delivery conveyor but each would have the ability to spray adhesive as well as handle the panels; i.e. the panel(s) will already have been picked up by the end effector and be moving with the end-effector while the adhesive is being applied. Once applied the end-effector is turned over and the panel(s) are applied.

The equipment required her is expected to be as follows:

		Each	<u>Total</u>
2-GMF S-500 robots	\$	100,000	\$ 200,000
2-Dual purpose end-effectors		6,000	12,000
spray and mat'l handling		. !	-
2-Adhesive systems		15,000	30,000
1-Panel delivery conveyor-8 ft		3,000	3,000
1-Stop, square and meter station	7	2,000	2.000
Total		ļ 1	\$ 247.000

Summary:

The total estimated cost is:

	· · ·	
1.	Application of hot melt spray adhesive	\$ 243,000
2.	Installation of 6 panels into case	368,000
3.	Affixing panel to back side of liner	131,000
4.	Affixing 3 panels to freezer and main	247,000
	door sets	-
5.	Project management and installation	50,000
	ervision	•

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We have reviewed these numbers with Tom Zito of Technical Equipment in Cincinnati, OH, and Bob Borgmann of Nordson in Florence, KY, who feel that they are adequate enough to be included in your report. Needless to say Jim, we are all looking forward to working with you and others on this project in the future.

I should point out Jim, that although we have followed a robotic scenario in this proposal, it is possible to come up with other automation alternatives in areas where the prices might be a little high for justification. This could be the case at the liner area and the door area.

Thanks again for giving us the opportunity to participate in your project.

Sincerely,

REMTEC, INC.

Charlie Gaynor Vice President

Sales & Marketing

CG/kjh

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